17 JUNE 1980 (FOUO 6/80) 1 OF 1

FOR OFFICIAL USE ONLY

JPRS L/9145

17 June 1980

USSR Report

SPACE

(FOUO 6/80)

FBIS FOREIGN BROADCAST INFORMATION SERVICE

FOR OFFICIAL USE ONLY

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

For further information on report content call (703) 351-2938 (economic); 3468 (political, sociological, military); 2726 (life sciences); 2725 (physical sciences).

JPRS L/9145

17 June 1980

USSR REPORT

SPACE

(FOUO 6/80)

Moscow NOVOYE V ZHIZNI, NAUKE, TEKNIKE, SERIYA 'KOSMONAVTIKA, ASTRONOMIYA,' in Russian No 3 (NAUCHNYY ORBITAL'NYY KOMPLEKS), 1980 pp 1-63

[Brochure by K.P. Feoktistov, professor, doctor of technical sciences, pilot-cosmonaut of the USSR, 30,300 copies]

CONTENTS

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200090031-6

SCIENTIFIC ORBITAL COMPLEX

Moscow NOVOYE V ZHIZNI, NAUKE, TEKNIKE, SERIYA 'KOSMONAVTIKA, ASTRONOMIYA,' in Russian No 3 (NAUCHNYY ORBITAL'NYY KOMPLEKS), 1980, pp 1-63

[Brochure by K. P. Feoktistov, professor, doctor of technical sciences, pilot-cosmonaut of the USSR, 30,300 copies]

[Text] In this brochure a study is presented of the "Salyut"-"Soyuz" orbital complexes. The author of this brochure, one of the creators of this complex, pilot-cosmonaut of the USSR, Prof K. P. Feoktistov, presents interesting data on systems, equipment, and the experimental base of the complex. He discusses the prospects for its development.

The brochure is designed for engineers, teachers and students of the institutions of higher learning and the technical high schools participating in the advance classes and also a broader class of readers interested in the modern achievements of cosmonautics.

A LITTLE HISTORY

In 1958 the Design Office of S. P. Korolev began work on the first future spacecraft, the "Vostok." Even then the participants in this work thought: "And what next? Where will we go after "Vostok"? Some thought the moon, others thought Mars, and still others thought orbital stations. The next year when we had still only begun the production of drawings, circuit diagrams, and the first parts of the spacecraft had begun to appear in the plant shops, the arguments about the future became still hotter.

The engineers were united — the path to the development of manned spacecraft lies in the solution of the problem of the rendezvous and docking of spacecraft in orbit. A group was formed which was charged with the investigation of this problem. This group was assigned the goals of discovering the technical problems connected with rendezvous and docking, planning versions of the solution, finding organizations which could develop the necessary equipment. At the beginning of 1962, the theoretical work had been completed by the efforts of this group, on the basis of which it was possible to proceed with the design.

The design problem was stated by the designers themselves, and then it was more precisely defined several times by S. P. Korolev. The decision was made to design a new spacecraft on which it would be possible to work out all the problems of rendezvous and docking. It was proposed that simultaneously this spacecraft would be used to increase the duration of flight, improve the living and working conditions of the crew, reduce the G-loads affecting man when returning to the earth, and expand the possibilities for performing research and experiments. It was thought that on the basis of this spacecraft with time it would be possible to create a transport unit for servicing orbital stations.

The work of designing the new spacecraft (subsequently called the "Soyuz") started in 1962. Obviously, that year has to be considered the year of the beginning of work on orbital stations.

The basic problems which were solved when developing the "Soyuz" spacecraft are the creation and the development of means of measuring the parameters of motion of two space vehicles relative to each other, the control of the rendezvous and docking process, the mechanical-electrical docking of the spacecraft, the creation of service propulsion engines and coordinate engines providing for the rendezvous and docking processes. In addition, it was necessary to create and develop in flight new systems for orientation and control, means of descending to the ground using aerodynamic lift (for reducing the G-loads when descending and for decreasing the dispersion of the landing part of the spacecraft when returning to the ground), a new landing system with redundancy of the parachute system, and so on.

In the middle of 1962, the first initial data were prepared for the development of the technical documents, and work was started on the preliminary design. As the drawings, the circuit diagrams of the individual systems and the ship as a whole and the test instructions, and so on were developed, it became clear that the "Soyuz" spacecraft was significantly more complicated than the "Vostok." Hundreds of instruments, thousands of parts, tens of kilometers of cables. All of this had to be connected into a unified operating whole; it had to be worked out in tens of experimental setups.

Whereas from the beginning of the design of the "Vostok" spacecraft (still unmanned) to its first flight took approximately a year and a half, the time required to build new spacecraft turned out to be appreciably longer. A great deal of time was taken up, for example, working on the simulation of the internal composition of the landing vehicle, the development of the heat shielding, means of applying it and checking out the fitness of it, aerodynamic and thermal studies, theoretical investigations of stability and control of the landing vehicle on returning to the atmosphere. The work on the new landing system required the creation of special models of the landing vehicle dropped from an aircraft and a large number of full-scale experiments. It was necessary to build a new propulsion unit, a system of control engines, new units for the heat regulating, life support and other systems.

Theoretical difficulties arose not only in the development of the system for determining the parameters of relative motion of two spacecraft (during rendezvous), the control system for this process, but also when creating the means of monitoring such systems on the ground before flight. Such means are created for all on-board systems and assemblies inasmuch as without a monitor check in the autonomous system and on the assembled spacecraft, not one instrument, not one system can be allowed to fly. The complexity of checking out the system for measuring the parameters of relative motion on the ground is connected with the fact that when checking out the system it was necessary to simulate the motion of two spacecraft relative to each other and check out its operation with relative mutual orientation of the spacecraft. Not only the functioning of the system is checked out, but also the accuracy of measuring the range, velocity, angles, and so on.

All of these operations took several years, and the first manned flight took place only in April 1967. It ended tragically: on landing, the pilot of the spacecraft, Cosmonaut V. M. Komarov, was dead. The reason for this accident was a failure of the parachute landing system. The uncalculated operating conditions of the parachute system were manifested on this flight although the flight of the first "Soyuz-1" spacecraft had been preceded by successful aircraft testing of the landing system and unmanned flights.

In 1967-1968, a large number of additional tests were run on the landing system. In October 1968, the spacecraft flights were again started. The flights of the "Soyuz" spacecraft in 1968-1970 made it possible to accumulate the necessary experience which permitted conversion to their use as transport vehicles. The most important milestones along this path were the flights of the "Kosmos-186" and the "Kosmos-188," "Kosmos-212," and "Kosmos-213" satellites to work out the problems of docking in the automatic mode in 1967 and 1968, the docking of two manned "Soyuz-4" and "Soyuz-5" spacecraft in 1969, and prolonged flight of the single "Soyuz-9" spacecraft in 1970.

In 1969 it became clear that the problem of rendezvous and docking of spacecraft was in practice solved. Next was the problem of creating the orbital station itself, and in 1970 work was started on building the "Salyut" station. The initial statement of the problem was defined as establishing a type of beachhead in the field of manned orbital stations. The decision was made to develop the first station as a laboratory on which the basic principles of creating manned orbital stations were to be studied, a number of scientific and technical experiments were to be run, and the possibilities of prolonged human flight in orbit to be investigated. The work on the "Salyut" station was participated in by many collectives of designers and specialists of the various design offices and scientific research institutes.

The "Soyuz" spacecraft was modernized simultaneously in order to convert it to a transport vessel for servicing the orbital station. Here the primary goal was to provide the possibility of transferring to the station through the docking unit (after docking the spacecraft with the station) in order not to have to use locks to make the transfer or cross through outer space in space suits. In order to solve the given problem, it was necessary to redesign the backing units significantly to say nothing of their operating system.

The document for the station and for modification of the "Soyuz" spacecraft (conversion to the transport version) was basically completed in the first half of 1970. The drawings for the hull of the station were completed in the spring. This made it possible to manufacture the station by the end of the year, and to insert it into orbit on 19 April 1971. The first "Salyut" station operated until 11 October 1971, having spent about a half year in orbit.

During the course of this first flight of the "Salyut" type orbital station a comprehensive check was made of the fitness of the station. Its equipment, the life support systems were studied under actual space flight conditions. Another goal was considered no less important. The prospects for the further development of the orbital stations, the manned space flights, mastery of outer space by man directly depend to a significant degree on how long man can work under weightlessness conditions. During the flight of the "Salyut" station, a new step was taken along the path of increasing the flight time of man in orbit. A crew made up of cosmonauts G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev lived and worked for 23 days on board the station. They felt satisfactory during this longest flight of the times.

It is necessary to note that before this flight the cosmonauts had never before dealt with such a quantity of on-board equipment. It is sufficient to state that the total mass of the equipment installed on board the station was measured in tons. In the future the saturation of the stations with equipment was to even be increased, and therefore it was necessary to check how the crew could deal with the execution of a broad, varied program, working with such a large quantity of instruments under prolonged flight conditions.

The station crew performed a series of astrophysical studies and technical experiments. It performed many visual observations and medical-biological studies and, the main thing, it made tests of the first orbital station in space flight. The experience acquired during the course of execution of the flight program made it possible to proceed with the building of improved stations. This flight demonstrated simultaneously that when building the "Salyut" it was necessary to find sufficiently simple and reliable engineering solutions for all of the station assemblies. Indeed, it was necessary to do this in the first pass: the "Salyut" was the first version of an orbital laboratory.

When the "Soyuz-11" returned to earth, before entering the atmosphere there was an emergency loss of seal in the spacecraft, as a result of which the crew died. After this flight, a number of changes were made in the design of the spacecraft; the crew was equipped with spacesuits in case of emergency decompression of the spacecraft in the most complicated parts of the flight: insertion into orbit, descent, docking (in these parts of the flight the crew must wear their spacesuits). The refinements made were checked out in ground tests and on a single flight of the "Soyuz-12" spacecraft in 1973. In subsequent years several "Salyut" stations were built and inserted into orbit.

Here I should like to discuss the "Salyut-4" and "Salyut-6" stations, for these stations operated for the longest time in the manned mode. On the basis of the accumulated experience, the "Salyut-4" station was modified significantly. First of all, it is necessary to note the modification of the power supply system (beginning with the "Salyut-3," solar cells which oriented themselves on the sun were introduced), the creation of an economical orientation system, and improvement of communications with the ground (telegraph communications of the earth -- a station with an alphabetic printer), the development of an experimental system for regenerating the water obtained from the atmospheric moisture condensate, expansion of the composition of the scientific equipment, and so on.

The "Salyut-4" station was launched at the end of 1974, and it stopped operating only in 1977 on instructions from the ground. Two crews worked on it for approximately 1 and 2 months. At the same time the next important step was made in increasing the duration of Soviet manned space flights. At the end of 1975, the unmanned "Soyuz-20" spacecraft was docked with the station in order to perform long-term resource tests on the spacecraft under orbital flight conditions in the station makeup. During flight of the station, numerous studies, observations and experiments were performed in astrophysics, geophysics, in the field of developing methods of studying natural resources and the environment, and medical-biological experiments.

The next theoretical step in the development of the work to modify the orbital stations was building the "Salyut-6" station, as a result of which it was necessary significantly to expand the possibilities of realizing prolonged manned flights.

The duration of a manned flight in the absence of systems on board the station to insure a closed material cycle[1], is determined by the stores of life support means and the possibilities of prolonged storage of oxygen, water, food, linens, domestic elements, hygienic materials, and so on. In addition, fuel is needed to control the orientation of the station and also for the control of its braking in the upper layers of the atmosphere.

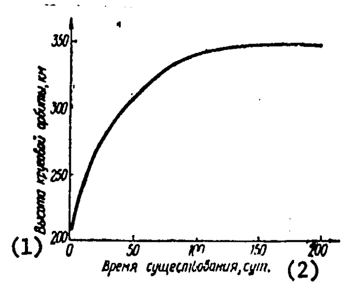


Figure 1. Time of existence as a function of height of circular orbit

Key:

1. Height of circular orbit, km
2. Time of existence, days

---

[1]Such a system exists at the present time, and it operates reliably only on the ground -- in its biosphere; the equipment providing for individual elements of the closed cycle is still only just being developed.

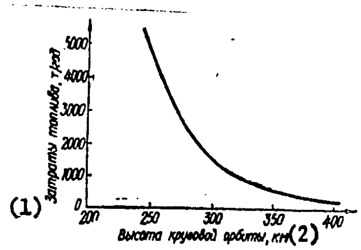


Figure 2. Fuel expenditures on maintaining orbit as a function of orbital altitude

Key:

1. Expenditures of fuel, tons/year
2. Circular orbit altitude, km

Two graphs are presented in Figures 1 and 2 which illustrate the time of existence of the station as a function of the orbital altitude and the quantity of fuel which must be spent per year to maintain its orbit. It must be noted that the fuel is also needed to correct the orbit, in order to insure optimal conditions for rendezvous with transport vehicles launched from the earth: before launching each spacecraft in turn it is necessary to "correct" the orbit so that the path followed by the station will pass over the launch site of the vehicle at the time it is launched.

If we remain on the level of the mid-1970's, it turns out that about 10 kg per man per day of stores are required for life support alone. In addition, it is necessary to add fuel and equipment which must be replaced in flight. If everything is taken into account, it turns out that in order to provide for the operation of the station in manned flight for 2 years it would be necessary to create about 20 tons of life support means and fuel on board the station. However, this exceeds the weight of the entire "Salyut-6" station. In addition, it has equipment designed for cosmonauts to work on board.

It was necessary to solve the problem of prolonged operation of the station in the manned mode by creating cargo transport vehicles to deliver equipment, food, water, oxygen, fuel, and so on to the station. In order that the station be able to receive the cargo vehicles, a dock with a docking unit was installed on board on the service module side, and a new combination engine was installed which could be refueled in flight from the cargo vehicles. Accordingly, the Soviet designers built the "Salyut-6"-"Soyuz" scientific orbital complex.

The work on the "Salyut-6" station and the "Progress" spacecraft began in 1973. The station was launched in 1977. In the elapsed time, several expeditions visited the station, including the international expeditions;

the "Progress" cargo vehicles flew to the station many times. They delivered equipment and refueled the station engine. The most important achievement obtained on the "Salyut-6" station was a significant increase in the given flight time under weightlessness conditions, as a result of which our country took the leading position in this field.

Structural Design of the "Salyut-6"-"Soyuz" Orbital Complex

The "Salyut-6"-"Soyuz" orbital complex includes the orbital station itself (or the orbital module), the manned transport vehicles "Soyuz" and the "Progress" cargo transport vehicles. The orbital module is the base for the complex: it provides the capability for the crew to live and work under space flight conditions, it provides for functioning of the complex (supplying of the station and the spacecraft with electric power, insurance of the necessary conditions for the crew to work and the equipment to function, maintenance of the orbital altitude, orientation, communications with the earth, and so on), and, finally, it provides for performing scientific-technical studies and experiments.

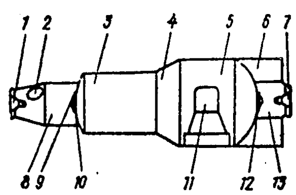


Figure 3. Station compartments: 1 -- forward docking unit; 2 -- exit hatch; 3 -- small-diameter zone of the working compartment; 4 -- conical part of the working compartment; 5 -- large-diameter zone of the working compartment; 6 -- service module; 7 -- rear docking unit; 8 -- transfer compartment; 9 -- forward bottom; 10 -- hatch between the transfer and working compartment; 11 -- scientific equipment compartment; 12 -- hatch between the intermediate chamber and the working compartment; 13 -- intermediate chamber

In order to maintain the necessary conditions for the crew to move and work on board, the orbital station must have a sealed inside volume with a gas atmosphere acceptable for man and with the corresponding temperature, means of eating, domestic services, and so on, and means of communicating with the ground, it must offer the possibility of observing outer space, it must have control means (orientation and on-board equipment), equipment for scientific-technical research and experiments, during the performance of which the direct participation of the crew members is required.

It is desirable that the sealed space and weight of the station be as large as possible: in this case a quite large amount of scientific equipment, oxygen, food, water, fuel, and so on will be placed on it. However, with an increase in the inside volume, the dimensions and the structural weight of the station increase, which contradicts with the capabilities of modern booster rockets available or specially built for insertion of the orbital module.

The booster rocket used to launch the "Salyut-6" station permits insertion of an orbital module with a maximum diameter of 4.15 meters and a length of about 13.5 meters. Greater dimensions of the station (in length or diameter) would lead to an increase in the load on the structural elements of the booster rocket and therefore are inadmissible. In addition, the orbital module is placed in the upper part of the booster rocket, and, consequently, its "upper part," where the so-called transfer compartment is located (Fig 3), must be fitted to the hull design of the nose cone, which terminates the upper part of the entire rocket and orbital module complex. This is necessary to insure an acceptable load level on the booster and expenditures of fuel to overcome aerodynamic drag in the segment of movement of the complex in the atmosphere. The restrictions with respect to size and, consequently, with respect to inside volume are determined in this way. The weight of the orbital module which can be inserted by this booster rocket is about 19 tons, which is the restriction with respect to weight of the module. When development the station it is necessary to begin with these restrictions and see to an efficient distribution of volumes (and dimensions, correspondingly) and weights among the various "users": the volumes required for the crew to live and work; the volumes and masses allocated for the propulsion units, equipment, life support means, scientific equipment, and so on.

Thus, when designing the station it is necessary to establish, and in all future phases of operations, constantly monitor the weight, dimensional and spatial budgets, always making them commensurable with the technical requirements and capabilities. During the development, the designers had to carry out and monitor an entire series of "budgets": the power supply (how much electric power the instruments, the systems of the station use in the various modes and how much of it can be obtained, using, for example, solar cells with given orientation of the station and with given position of its orbit with respect to the direction of the sun), heat (how much heat is released inside the station by the crew and instruments, how much of it gets into the station from external sources such as the radiation of the sun and earth, and how much heat is radiated into outer space through the radiators and other external elements), oxygen and carbon dioxide in the station atmosphere, water on board (how much the crew consumes, how much is released by them into the station atmosphere, how much water can be purified and used, how much water will be absorbed by the regenerators, how much is adsorbed on the structural elements and equipment, how much water must be used per day in order to close the budget), and so on.

Finally, it is necessary also to consider the time "budget," which is expended on the performance of the corresponding operations in outer space (correction of the orbit, rendezvous, docking, fueling, transfer of cargo, repairs, waste, and so on), medical monitoring, communications, rest, eating, physical training and the performance of research and experiments. In reality, with respect to all of its parameters, the station, just as a spacecraft, just as any complex machine, is designed considering a compromise between what is desired and what is possible.

The dimensions of the "Salyut-6" station in practice determine its inside sealed volume equal approximately to 90 m^3, the basic part of which goes to the working compartment. In addition to the working compartment, the station has two other sealed compartments (connected to the working compartment through hatches): the transfer compartment (2 meters in diameter), and the intermediate chamber (see Fig 3). The manned transport vehicles are docked to the transfer compartment, and it serves as the connecting link between the spacecraft and the orbital module.

In addition, the transfer compartment is used as a lock for exit of the cosmonauts to outer space. Therefore there are spaces in it for working in outer space, their on-board equipment, fittings, the pressure release valves, monitoring and control panels. There are seven windows in the walls of this compartment which are used by the crew during visual observations or experiments connected with visual observations of the earth, the moon and the horizon.

The cargo and manned transport vehicles are docked with the intermediate chamber. This chamber which is 2 meters in diameter and 1.3 meters long is used as the buffer space between the working compartment of the station and the transport vehicles. It is used for partial placement of the delivered cargo. Air ducts are run from the station to the spacecraft through the transfer compartment and the intermediate chamber after docking in order to ventilate the inhabited compartments of the spacecraft.

The working compartment is the main compartment of the station; the crew lives and works in this compartment; the basic equipment of the station is placed there. The structural design of the hull of this compartment must insure reliable seal of the inside volume (it is natural that these requirements are also valid for the transfer compartments and for the intermediate chamber), protection from the effect of the external vacuum, protection of the crew and the instruments from the effect of micrometeorites; it is permissible to place instruments and assemblies on the outside surfaces which are positioned to "see" into outer space: the sensitive elements of the orientation system, solar cells, optical devices, scientific equipment (which cannot "operate" through the windows), antennas, radiators, and so on.

The creation of an all-welded structural design of the hull of the spacecraft would be ideal for the solution of the problem with respect to sealing the spacecraft, but this is in practice impossible. There are an entire series of factors interfering with this solution. In particular, it is still not possible reliably to weld glass and metal without disturbing the optical characteristics of the glass. For technological arguments it is undesirable to weld the hull of the working and transfer compartments, the working compartment and the scientific equipment compartment: thousands of electric wires and a large number of hydraulic lines must run through the sealed outline of the compartments on the outside. Finally, it is necessary periodically to connect the inside volume to outer space (for example, for ejection of waste).

Therefore, in designing the hull of the station it is necessary to introduce hundreds of split sealed connections which, as a rule, are sealed by rubber inserts. The choice of materials and structural designs of these seals must be made considering the thermal conditions of the sealing locations, the mobility of the joint, the required open-shut reserve,the effect of the external hard (primarily, ultraviolet) radiation (if this seal is directly on the outer surface), and so on.

In recent years when the duration of the manned flights increased sharply, the problem of protection from micrometeorites became more acute. During the flights of the "Vostok" and the "Voskhod" and in the first years of the flights by the "Soyuz" spacecraft this problem in practice did not exist. On the basis of the theoretical and experimental research, it was established that the probability of breakdown of the sealing wall of the spacecraft by a micrometeorite is very small and it amounts to hundredths and even thousandths of a percentage for a flight time of the cosmonauts of several days (considering the size of the spacecraft). These results of calculating the probabilities are based on various models of the micrometeoritic cloud in the vicinity of the earth's orbit and the properties of the interaction of the meteorites with the material at the spacecraft wall.

At the present time the duration of the space flights is reckoned in months (for spacecraft) and even years (for orbital stations). Here the probability of breakdown of a single-shell design of a space vehicle by micrometeorites comes quite large, and it must be taken into account when designing the scientific orbital complex. In the modern stations it is simply impossible to use a single-shell structural design for the hull of the sealed compartments.

Usually in the structural design of the hull of the working compartment, in addition to the sealing shell, screens are used which are installed at a defined distance from the shell itself. The essence of the given method of protection against the danger of micrometeorites consists in the following. On collision with the shield, the micrometeorite explodes (inasmuch as the speed of movement of the particle with respect to the station is 10-30 km/sec!), and the remains of the micrometeorite and the destroyed shield material, expanding rapidly (in the form of a jet) lose energy which would permit the particle to penetrate into the sealed volume.

Part of the hull of the working compartment of the "Salyut-6" was enclosed in the radiator of the heat regulating system of the station which at this point plays the role of an antimeteoritic shield also. The remaining part of the hull of the working compartment, the hull of the transfer and the intermediate chamber is protected either by special antimeteoritic shields or by other structural elements (the panels of the heat regulating system, the shell of the service module, and so on).

The sealed hull of the working compartment is formed of two spherical bottoms (forward, on the transfer compartment side, and the rear, on the intermediate chamber side) and two cylindrical surfaces (one 2.9 m in diameter and 3.5 meters long, the other, 4.1 m in diameter and 2.7 m long). These two cylindrical structures are joined by a conical surface (1.2 meters long). On the shell of the large-diameter cylinder (4.1 meters) there is a hole in which the scientific equipment compartment is installed. There, too, in the direction opposite to the scientific equipment compartment, two locks are installed for ejecting waste. The hull of the scientific equipment compartment is simultaneously part of the sealed hull of the working compartment (see Fig 3).

The choice of this sealed layout of the working compartment arises from the following restrictions: the total length of the sealed compartments must not exceed 13.5 meters, a maximum diameter (considering the heat shielding) of 4.15 meters, and the configuration of the forward part must be fitted inside the cone of the outer shape of the upper part of the rocket and orbital module complex. It is true that it is possible to make the entire working compartment in the form of one cylinder 4.15 meters in diameter. But then it would be impossible to place the solar battery inside the stipulated outer boundary of the complex. The decrease in diameter of the working compartment in this part to a length of 2.9 meters is also designed to install the solar batteries of the power supply system made up around this cylinder, there.

This entire part of the hull of the working compartment together with the solar cells and the transfer compartment is enclosed by the nose cone which is ejected when the rocket leaves the dense layers of the atmosphere in the orbital insertion segment of the flight. The nose cone provides protection against the velocity and heat fluxes (in the generation section) not only for the solar cells, but also the antennas located on the outside surfaces of the transfer and working compartments (2.9 meters in diameter) and the optical indexes of the rendezvous system, the optical sensors of the automated orientation systems of the station and solar cells,the optical instruments for visual orientation in the case of manual control of the station, scientific equipment, panels with the heat regulating system units, the heat regulating system radiator (on the outer surface of the part of the working compartment).

The inside volume of the working compartment is divided into two primary zones: instrument (where the instruments and assemblies are primarily placed) and living (where the crew lives and works). The instrument zone is placed along the walls of the station on the right and left sides, on the sealing, on the floor and in the vicinity of the rear bottom. Of course, the "right" and "left" (and the implied concepts of "forward" and "back" respectively) are provisional concepts for a spacecraft. For the "Salyut" stations, we mean the following. On one side of the working compartment there are optical infrared sensors for constructing the local vertical, the axis of which is perpendicular to the longitudinal axis of the station. For orbital automatic orientation their axes coincide with the local vertical, and this side is turned toward the earth (that is, "downward") for orbital orientation.

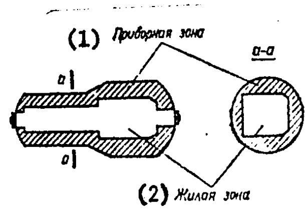


Figure 4. Instrument and living quarters of the working compartment

Key:
1. Instrument zone
2. Living quarters

On this side instruments are installed for visual orbital orientation with manual control (which are also turned "downward"). The MKF-6M and the KATE-140 cameras designed to photograph the earth's surface also "look" in the same direction. Therefore the given side is also provisionally considered the floor of the station.[1] The "forward" direction is defined as the direction of the transfer compartment (it corresponds to the "forward" direction in the orbital insertion part of the trip). Finally, from these two defined directions, the "right" and "left" sides of the station are uniquely defined.

The instrument zone (Fig 4) is separated from the living quarters by panels, for the most part easily removable, for access to the instruments and units in case it is necessary to inspect them or replace them in flight. The control panels and displays are either located directly in the living quarters or they are cut into these panels. In the instrument zone there is equipment for the control systems for the on-board complex, orientation and control of the movement of the station, telephone communications with the earth, a command radio link, television systems and also telemetry systems, systems for orbital monitoring, power supply (buffered batteries

---

[1] Although more frequently the orbital station is realized without fuel consumption -- by means of gravitational forces -- and then the local vertical is connected with the longitudinal axis of the station.

and automation), life support, medical monitoring, and part of the heat regulating system automation. By using the fans, the gas-liquid and cold drying units, the air is circulated through the instrument zone and heat released by the instruments during their operation and from the air moving through the instrument zone into the heat regulating system of the station is removed.

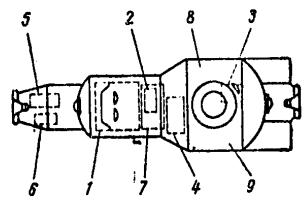


Figure 5. Location of the control stations:
1 -- station No 1; 2 -- station No 2; 3 -- station No 3;
4 -- station No 4; 5 -- station No 5; 6 -- station No 6;
7 -- station No 7; 8 -- right side; 9 -- left side

The residential quarters take up all of the remaining volume of the working compartment. In them it is possible to isolate the control station at which the crew controls the station, performs studies and experiments, carries out medical monitoring of the condition of the entire organism and also the zone for the performance of physical exercises, places for eating and sleeping, and for the sanitary-domestic needs (toilet, shower).

In the working compartment there are five control stations connected with the execution of defined operations (see Fig 5). Station No 1 is the central control station. It has two work areas. There is a main control panel with command signal signals for issuing commands with an indicator of the station position (as points) relative to the surface of the earth, indicators of the automatic programs being executed, optical and sound signals, clocks, and so on. The optical instruments for visual orientation with respect to the earth, the control panel for the on-board computer, the information unit -- all are installed here.

Station No 2 is used for manual astronavigation of the station. It is equipped with a panel, communication media, astronomical instruments and a control handle. Station No 3 is designed to control the submillimeter telescope and the autonomous cooling system of the telescope receivers. This station is also equipped with panels, communications media, a viewer and control handles. The medical-biological equipment is worked with at station No 4. This station is in the lower central part of the working compartment at the junction of the large and small-diameter cylinders. The equipment for movie and photographic surveying is placed here. Finally, station No 7 (stations No 5 and No 6 are located in the transfer compartment) is used to work with the control panels of the system for regenerating water from condensate and scientific equipment. All of the stations are equipped with lights and communication media.

The zones for performing physical exercises are located near station No 4. On the first long flights the necessity for so-called weightlessness prophylactics was discovered. The fact is that under the conditions of prolonged orbital flight when a man is not under the effect of gravity, the load on the heart decreases noticeably (the heart does not have to overcome the hydrostatic pressure of the blood on the order of 0.15-0.2 atmospheres); the groups of muscles providing for the possibility of standing, walking, sitting, and so on are not loaded, the internal muscles supporting the internal organs (lungs, stomach, liver, intestines and so on) are not loaded, and finally the skeleton itself is not loaded.

All of this, if preventive measures are not taken, can lead to some muscular atrophy and to defined difficulties in readapting to the earth's gravity on return of the crew to the ground after a prolonged flight. This was observed, for example, by the American astronauts F. Borman and J. Lovell after their return to earth after a 14-day flight on the "Gemini-7" spacecraft in 1965, inasmuch as during that flight they were in practice unable to move actively. It was also noted by A. G. Nikolayev and V. I. Sevast'yanov after their return from an 18-day flight on the "Soyuz-9" spacecraft in 1970.

At the present time the most suitable means of controlling the effect of weightlessness is the use of special devices on board the orbital station -- trainers designed to provide noticeable additional load on the heart and basic muscle groups when performing physical exercises. These means include the veloergometer,[1] treadmill, and a pneumovacuum suit. The treadmill, as is clear from its name, is an endless belt on rollers driven by an electric motor. The speed of the belt can be regulated, at the same time regulating the speed of walking that must be maintained by the cosmonaut exercising on the treadmill.

Naturally, the speed of the belt is regulated by the cosmonaut himself. In order that he not "fly" off the treadmill while walking, it has a system of elastic straps (with adjustable tension on the order of several tens of kilograms), one end of which is fastened to the belt of the cosmonaut, and the other, to the stationary part of the treadmill. The tension of these straps in some degree simulates the loads during walking and running on the feet, the leg muscles, the bone tissue, and so on.

The pneumovacuum suit is a sealed container worn by the cosmonaut on the legs and the lower part of the body and sealed at the waist. The vacuum pump creates rarefaction inside the cavity on the order of 30 to 60 mm Hg,

---

[1]The veloergometer is a type of bicycle which runs an electric generator. It is true that the electric power generated by this generator (alas!) is useless: it heats up the air, lost in the ballast resistances. However, by adjusting these resistances it is possible to regulate the load which the cosmonaut must overcome when pedalling the veloergometer.

it makes it possible to create some additional hydrostatic load on the heart.

The veloergometer is located on the "ceiling" of the station. The treadmill and the pneumovacuum suit are located on the "floor," in the vicinity of the conical adapter. In accordance with the on-board instructions (which are law on board the station) the crew must exercise 2 to 2-1/2 hours a day on these trainers. Flight practice has demonstrated that such means are quite effective for the tested flight times.

In the rear section of the station there is a toilet cabinet with cesspool which provides for the collection of waste from the vital activity of the crew and for purification of the station atmosphere. The urine and solid waste are collected in special sealed containers which are then ejected as they are filled into outer space through locks. A shower stall is unfolded when needed in the vicinity of station No 4. After taking a shower the stall is folded back up.

The bunks for the crew are located on the side panels and on the "ceiling" where the sleeping bags can be attached. The cosmonauts eat breakfast, dinner and supper at the table located in the vicinity of the station No 1. The food heaters, the eating facilities, means of fastening a water tank and food tank are located here.

In addition to the sealed compartments, the station includes two unsealed compartments: the scientific equipment bay and the service module. The hull of the scientific equipment bay (see Fig 3), as was stated previously, is part of the sealed shell of the working compartment. It is a truncated cone, the inside volume of which is open to outer space. The scientific equipment which cannot "operate" through windows is installed in the hull (on the "Salyut-6" station this includes the BST-1M submillimeter telescope; on the "Salyut-4" station, the OST-1 solar telescope, the "Filin" and the RT-4 x-ray telescopes, the ITSK infrared telescope, and the spectrometer). In the orbital sections where the scientific instruments are not used, the compartment is closed against outer space by an unsealed cover with vacuum shielded thermal insulation designed to protect the scientific instruments from sun beams and insure thermal conditions for the compartment (so that the compartment will not cool off as a result of radiation in outer space).

With respect to appearance the service module is a cylinder 4.15 meters in diameter and 2.2 meters long with two end frames, one of which is fastened to the lower end frame of the working compartment and by the other the service module is connected to the supporting frame of the booster rocket. In the service module are the tanks, the pneumohydraulic automation, fittings, service propulsion and control engines of the combined power plants. In addition, the antennas, targets and light indexes of the rendezvous system and also the antennas of the other radio systems are installed in this module.

"Salyut-6" Station Flight Systems

Orientation and Motion Control System of the Station (SOUD). Jointly with the servoelements (the control and service propulsion engines of the combined power plants) the following problems are solved by this system: 1) automatic orientation of the station (in the orbital or inertial coordinate systems) for the performance of scientific observations or experiments; 2) generation of the directional correction pulses for raising or correcting the station orbit (when preparing the orbit for rendezvous with the transport vehicles); 3) orientation of the station in the rendezvous process on the approaching transport ship, participation in radio exchange of signals with the transport ship required to determine the parameters of relative motion of the station and the spaceship; 4) orientation of the station (in the orbital or inertial coordinate system) with "manual" control by the crew.

The SOUD includes various sensitive elements: gyroscopes, angular velocity gauges, longitudinal acceleration integrators, infrared plotters of the local vertical, solar and ionic sensors and also the optical orientation instruments: with respect to the earth's horizon (for constructing the local vertical with manual orientation in the orbital coordinate system), with respect to the apparent direction of "travel" of the terrain (for construction of the orientation with respect to the flight direction), by the stars (celestial orientation devices and a sextant). In addition, the SOUD includes the radio rendezvous equipment which jointly with the radio equipment of the transport ship provides for measuring the relative parameters of motion and also the electronic, logical, calculating and commutation devices.

The achievement of one goal or another, as a rule, can be insured by the SOUD in various modes and using various sets of instruments. Thus, for example, the orientation of the orbital coordinate system can be insured as a result of operation of the infrared local vertical plotter jointly either with the ion sensors (with corresponding calculation modules) or with solar sensors, or with the "Kaskad" economical orientation system and, finally, by manual control.

This property of the SOUD provides deep functional redundancy in the given system.

Combined Power Plant (ODU). Its goals are the following: 1) the output of pulses to change speed and direction of motion of the station to raise or correct the orbit, 2) the creation of contr l thrusts as a result of operation of the control engines for orientation of the station or to maintain the given attitude of the station in space. The pulse output can be realized as a result of the operation of one or two liquid-propellant service propulsion jet engines located at the end of the service module with a thrust of 300 kg each.

Inasmuch as the required range of the control pulses is quite broad (from minimal for maintaining economical orientation to highly significant during rendezvous with a transport vehicle, especially when one ship is already docked to the station), then several jet control engines must be installed on each of the control channels, and they can be included both individually and in groups. With respect to the pitch and heading channels (that is, for the creation of moments around the axes perpendicular to the longitudinal axis of the station), from one to six control engines can be switched on, and for the bank channel (that is, around the longitudinal axis), two or four engines can be switched on. The thrust of each control engine (a total of 32 of them) is about 14 kg-force.

In addition to the service propulsion and control engines, the ODU includes six tanks (where fuel is stored), the purging tanks with gas (for forcing the fuel out of the tanks into the main lines from which it goes to the engines), compressors, hydropneumatic automation (pressure reducers, the pneumohydraulic valve, the pressure gauges and temperature gauges), the commutation and logical devices, and the hydropneumatic lines.

In the tanks the fuel is separated from the purging gas by using metal bellows separators. If there were no such separators, the gas and fuel would be mixed under weightlessness conditions, and the engines would receive gas, fuel and a gas-liquid emulsion alternately, which could lead to failure of the engines or to other inadmissible deviations. Usually flexible separators made of organic films have been used in the power plants of space vehicles as the fuel and purging gas separators. In the ODU of the "Salyut-6" station it was necessary to convert to metal separators in order to provide for multiple filling of the tanks and prolonged storage of the fuel.

The compressors are used for preparing the ODU for filling, during which the gas is pumped out of the gas cavity of the fuel tanks into the purging tanks (both the service propulsion and the control engines are supplied from the same tank). Nitrogen tetroxide is used as the oxidizing agent, and asymmetric dimethyl hydrazine is used as the combustible component of the fuel.

All of the units and the pneumohydraulic automation of the ODU are placed in the service module. Inside the module and on its surface (where the engines are located) positive temperatures are maintained as a result of pumping the liquid heat transfer agent through the lines welded to the sheathing of the module. The temperature of the heat-transfer agent is regulated by the heat regulating system of the station. The engine instruments are installed in the working compartment.

Electric Power Supply System (SEP). The purpose of this system, as follows from its name, is the supply of DC and AC power to the on-board systems and scientific equipment. The SEP includes solar cells, storage batteries, DC-AC inverters, and control automation.

The photoreceivers of the solar cells are installed on three panels, each of which has an area of about 20 m^2 and a multiply folded frame structure. The latter arises from the fact that in the phase of insertion of the station into orbit, the solar cells must be packed in a tight space between the nose cone and the cylindrical hull of the working compartment.

After insertion of the station into orbit, each of the panels is unfolded. The base of the panel is fastened to a special drive which turns the solar cell around the axis perpendicular to the longitudinal axis of the station. At its base there is a shield which, after unfolding the panel, prevents radiation exchange between the solar cells and the radiator of the heat regulating system located on the same cylindrical surface. Two solar cells are arranged in the "lateral" directions ("right"-"left") and one, "at the top." The fourth panel, which could occupy the "bottom" is absent; in other words it would interfere with the field of view of the optical sensors, spectrometers and the visual orientation instruments installed in this part of the station.

The joint operation of the solar cells, storage batteries and current users is provided for by using the SEP automation which protects the storage batteries from overcharging (by using voltage pickups on the primary feed buses and pressure gauges in the individual storage batteries). The same automation protects the system from overcharging by using the minimum voltage sensors and excluding part of the on-board users if the voltage falls below the admissible amount.

The dynamic state of the buffered storage batteries is controlled by using ampere-hour meters (the consumption and intake of power in the system are monitored) and voltage gauges on the feed buses. The monitoring is provided both telemetrically (at the flight control center) and on the control panel (on board the station)

Solar Cell Orientation System (SOSB). This system includes a set of sensitive elements which "look at" all of outer space; the electronic modules which generate the signals from the sensitive elements; the commutation devices and the drives for the solar cells. The system operates autonomously and in practice continuously for the entire flight time of the station.

By the signals from the sensitive elements, the logical device determines in what direction the sun is located with respect to the station and how each panel of the solar cells should be rotated around its axis so that it will receive maximum amount of solar power. The sensitive elements are arranged in groups on the forward end of the working compartment and on the after end of the service module.

The structural line of the drives for the solar cells provides not only for rotation of the solar cells, but also the transmission of electric power, commands and high-frequency information through the rotating connection (the radio system antennas are installed on the ends of the solar cells).

Heat Regulating System (STR). The goals of the STR include the following: 1) maintenance of the air temperature inside the sealed compartments of the station and the crew quarters of the docked spacecraft acceptable for the crew of the orbital complex; 2) maintenance of the required temperature conditions in the instrument area of the working compartment; 3) insurance of the thermal conditions of the unsealed compartments and all the elements, instruments and units located on the outside surfaces of the station; 4) maintenance of the thermal conditions of the spaceships docked to the station.

The STR is made up of several hydraulic circuits and passive media. The hydraulic circuits include the following: 1) the loop for removing the heat from the atmosphere of the working compartment (the inside cooling loop); 2) the loop for thermostating the hull of the station; 3) the loop for heat output to the outside radiator (the outer cooling loop). Each circuit includes lines filled with liquid heat-transfer agent, pumps, condensers (to compensate for the variation in volume of the heat-transfer agent when the temperature changes), liquid-liquid and gas-liquid heat exchangers, the regulating cocks, temperature gauges and various valves.

The circuits for removal of heat from the air and the circuits for thermostating the hull are filled with nontoxic and fireproof coolant (the antifreeze type), and the outer radiator of the circuit is filled with organosilicon coolant which retains its operating characteristics at temperatures no lower than -70°C. The greater part of the units of all of the circuits (pumps, compensators, valves, and so on) are put together on special plates outside the sealed compartments. The temperature of the liquid in the inner cooling circuit is automatically regulated with an accuracy of ±2°C with respect to one of the selected ratings: 5, 7 and 9°C.

The heat is removed from the air either by using a cooler-drier (where the atmospheric moisture is condensed simultaneously with subsequent exhaust of the condensate to the moisture pickups) or using gas-liquid heat exchangers (of the automobile radiator type). The cooler-driers and the gas-liquid heat exchangers include a fan to provide for the air flow between the tubes of the heat exchanger and the air flow rate regulator (a shutter with drive) which regulates the heat flux from the air to the cooling surface.

The sensitive element, by the readings of which the air flow rate is regulated in the automatic mode is the air temperature gauge. In the living areas of the station a temperature is maintained of 18-25°C, the moisture is kept within the limits of 20 to 80%. In addition to the cooler-driers and the gas-liquid heat exchangers, the air circulation in the station is maintained by a system of fans, part of which are located in the instrument area and part in the crew area. In the crew area the blowing speed is within the limits of 0.1 to 0.8 m/sec.

The heat and gas exchange between the stations in the docked spacecraft is realized through air ducts (with fans) and an intermediate hydraulic circuit (part of it is located on board the space craft, and part on the station) for heating the transport vehicle. This circuit is closed when the space ship is docked with station. The necessity for such measures (with respect to heating the space ships) is connected with the fact that after docking of the space ship, the greater part of its equipment is switched off, and the crew in practice works at all times in the orbital module and, consequently, the heat release inside the space ship is decreased sharply.

The passive heat regulating means include the packets of vacuum shielded heat insulation covering all the surfaces of the station not taken up with radiators, engines or sensitive elements and separating the radiators from the hull. All of the elements of the heat regulating system are redundant.

Life Support System (SOZh). The problems solved by the life support system are highly varied and require the use of a variety of equipment. The life support means include the following: a system for maintaining the gas composition, water supply equipment, feeding devices, cesspool and sanitation unit, locks, shower, routine sanitation equipment, clothing, pharmacy, means of medical monitoring the condition of the crew organism and also the weightlessness prophylactic means.

The system for maintaining the gas composition must insure the atmospheric parameters inside the station necessary for sustaining normal life condition of the cosmonauts: with respect to overall pressure (within the limits of 700 to 960 mm Hg), with respect to partial pressure of oxygen (within the limits of 160 to 240 mm Hg), with respect to the partial pressure of carbon dioxide (within the limits of 0-9 mm Hg), with respect to harmful gas impurity content (within the admissible limits). The system includes regenerators, harmful impurity filters, compressed air tanks, gas analyzers, and means of monitoring the atmospheric pressure.

The regenerators are cartridges filled with chemicals. On pumping air through them (by means of a fan) they absorb the carbon dioxide and moisture and release oxygen. The regenerators are disposable -- each of them, after being switched on, gradually is saturated and then ceases to operate, after which the next must be switched on, and so on. The store of regenerators initially installed (on the earth) provides for the crew's living for the first 3 months. For continued work in the manned mode beyond this period it is necessary to deliver and install "fresh" generators on the station regularly and remove the spent ones in order to prevent them from taking up inside space.

The harmful impurity filter absorbs the gas impurities which get into the station atmosphere as a result of the vital activity of the crew and the release of any type of materials used in the structural design, in the instruments and cables of the station. The filter is filled with activated charcoal, chemical absorbent and materials that catalyze the process. The air is pumped through the filter by a fan.

For each exit of the crew from the station into outer space a volume of air is lost to the outside from the transfer compartment (about 6 m^3). In addition, for each ejection of a container with waste through the locks, gas is lost. Not only oxygen, but also nitrogen is lost. In order to compensate for these losses, compressed air is delivered as needed by the freight spacecraft, and it is released into the station atmosphere.

The gas analyzers monitor the composition of the atmosphere with respect to oxygen, carbon dioxide and moisture. Air samples are taken as needed and delivered to the earth where the station atmosphere is monitored for harmful gas impurities and microbes.

The pressure is monitored by a system of gauges and pressure signals (to signal the crew in case there is a leak in the station), the readings of which are transmitted to the central panel and to the earth (through the radiotelemetric system) and also by a precision pressure gauge. This system includes valves and elements to control them which with the hatches closed, provide for equalization of the pressure between compartments, between the station and the docked spacecraft (which is necessary to allow for opening the hatches) and release of the pressure from the transfer compartment before the crew exits to outer space.

The water supply means include the system for regeneration of water from condensate, various tanks for the delivery and storage of water and also devices for receiving water. The system for regeneration of water from the condensate was tested on the "Salyut-4" station. It uses moisture collected from the atmosphere of the station by the STR cooler-driers. The moisture enters the cabin atmosphere as a result of breathing of the cosmonauts and release of moisture by evaporation through the skin. There is approximately the same amount of carbon dioxide and water vapor in the gas exhaled by a human. Each crew member releases about 1 kg of water per day into the station atmosphere.

The container with the condensate is connected to the water regeneration system. The condensate is pumped through ion-exchange columns, it is sterilized, heated and goes to the water batching unit. Inasmuch as the system for regeneration of water from condensate does not fully meet the crew's demand for water, water that is delivered gradually in various containers is also used. Before putting the water into these tanks, it is converted by introducing ionic silver into it (this method of conserving water has been known since ancient times). The cosmonauts are fed several times a day on the station. Their menu includes canned meat, pates, soups in tubes, juices, tea, coffee, cheese, bread, and confectioneries. Part of the food is used cold, and part -- the main courses and any type of puree in tubes, coffee -- is heated before consumption. In addition, produce deliveries (with apples, onions, garlic and so on) are made on board the station as selected by the crew in practice on each "occasion" (that is, with the manned and cargo spacecraft).

The cesspool and sanitation unit is designed to remove liquid and solid products of the vital activity of the organism of man. The liquid excrements are carried away by a flow of air into a special collector. The liquid remains in the collector, and the air passed through a filter is returned to the station atmosphere. After they are full, the collectors are ejected through locks. The solid waste is collected in individual small containers stored in sealed containers which are ejected after they are filled. The tanks for the liquid waste and the containers for the solid waste of vital activity are delivered on the cargo spacecraft as needed. Each of the two locks installed on the station for ejection of waste is made up of a stationary housing connected to the sheathing of the working compartment and is a part of its sealed hull and a moving inside hull. Both hulls have a spherical shape. When loading the lock with the container, the inside hull is turned with its hole inside the station, and it is clamped by its rear (opposite to the hole) part through a sealing ring to the exit opening of the stationary housing separating the sealed volume of the station from outer space.

After loading, the hatch cover is closed, the air is discharged from the chamber, and the inside housing is removed from the seal and turned with the hole out to discharge the container. The discharge is realized using a spring mechanism and a system for releasing it. As a result of braking in the atmosphere, the discharged containers gradually lose altitude, and after several months they fall into the dense layers of the earth's atmosphere and burn up.

The shower of the "Salyut-6" station operates on the water stored on the station (the water in the shower is heated before use). The cosmonaut takes a shower in a cabin made of organic film. The heated water is supplied under pressure to the spray head of the cabin and is removed from the cabin by the flow of air pumped through the moisture collector from the cabin. The moisture and the detergents are collected in the collector in this case, and the air passed through the filter goes to the atmosphere of the cabin.

The routine sanitation equipment also includes the things needed for hygienic use: electric razors, toothbrushes, toothpaste, wash cloths, towels, combs, and so on.

The medical monitoring of the condition of the organism of each crew member is realized approximately once every 10 days. During the time of the monitoring, the crew wears special belt with a system of sensors and is connected to a control unit which makes it possible to take an electrocardiogram, an electroencephalogram, and so on. The recordings of the medical parameters are made both with the cosmonauts in the quiet state and against a background of load or when performing special tests.

In order to estimate the condition of health, in addition to these measurements, the observations by the crew themselves were used (reported daily to the earth) along with objective data on fitness and appetite, observations during television reports and radio sessions, regular monitoring of body weight of the cosmonauts using a mass meter.

The spacewalk support means include spacesuits, on-board equipment providing for testing and functioning of the spacesuits before going outside and also a control panel for the spacewalk. The spacesuits are the semi-rigid type; they can be donned in calculated minutes. The autonomous work time of a man in a spacesuit is about 5 hours. The spacesuit systems provide for communications with the partner on the spacewalk and (through the on-board station) with the earth, the oxygen supply for the man, the removal of water vapor and carbon dioxide from the inside cavity of the spacesuit, the thermal conditions, seal and protection of the eyes from direct sunlight. The design of the spacesuit offers the possibility of moving freely, applying force and working with the fingers of the hands.

Station Radio Equipment. The radio complex provides for two-way radio tele-telephone communications with the earth from on board the station and when a crew member is on a spacewalk, reception and output of telegraph communications to the crew in the form of printed material (texts and tables), telephone communications between the station compartments and with approaching transport vehicles, transmission of television images to the earth, reception of television information from the earth on board the spacecraft, telemetric measurements, radio monitoring of the orbit, transmission of the control commands from the ground to the station, "settings" and digital data for the on-board computer, and coordination of on-board time by ground time.

The telephone communications with the ground and between spacecraft are realized by redundant radio channels in the ultrashortwave, decimeter and shortwave band and telegraph communications in the shortwave band. The communications equipment includes receivers, transmitters, the corresponding automation, commutators, control elements, antennas, acoustical equipment (telephones, loudspeakers, microphones, and so on).

The television set makes it possible to transmit both black and white and color images to the ground. During the third basic expedition, a television receiver was delivered to the "Salyut-6"-"Soyuz" orbital complex, and it was connected to the on-board antennas which made it possible to receive black and white images from the ground.

The transmission of telemetric information to the ground is provided for by using two multichannel radio telemetric systems with redundant memories. The telemetric information contains the results of scientific measurements, the data from medical monitoring of the crew, the parameters of the atmosphere and the thermal conditions of the structure, the internal and external elements of the station, data on the operation of the mechanisms, units and instruments. These data are transmitted over the radio channels to the ground stations located in the USSR and on marine ships used in the radio communications system with the station. The information received at the ground stations is transmitted to the flight control center, it is processed as it arrives on the ground computers and there it is output to the duty personnel of the control center on displays. The information is recorded at the same time in the form of graphs and tables.

Radio monitoring of the orbit is realized by using two transponders and ground measuring devices. The processing of this information in the ground computer centers makes it possible to calculate the orbit of the station and output the information required to correct the orbit, determine the launch times of the spacecraft, the performance of long-range rendezvous of the spacecraft and station, the organization of communication sessions, coordination of the results of the studies with the position of the station relative to the earth's surface on board the spacecraft, to the flight control center and to the network of ground measuring command stations.

The reception of command and digital data on board is provided for using receiving, decoding and switching devices.

Docking Assembly. The docking assembly is made up of two types of special units (docking units): passive and active. The two passive docking units (cones) are installed on the stations; the active docking units (the "pin" type) are installed on the manned and the cargo transport spacecraft. The docking assembly provides for the following: 1) the selection of the admissible deviations during docking and mechanical lock-on when the spaceships and the station make contact; 2) extinguishing of relative angular vibrations (of the spaceship and the station) occurring as a result of the fact that the direction of the relative velocity of the spacecraft does not intersect the center of mass of the station; 3) equalization of the axes of the spacecraft and the station; 4) contraction of the latter before contact of the end planes of the docking units; 5) sealing of the pin; 6) passage of the crew from the spacecraft to the station and back. All these functions are realized during joint operation of the mechanisms and automation of the docking assembly.

The active docking unit is made up of the docking mechanism (the "pin" type) and the structural ring with the sealing mechanisms, the elliptical and hydraulic plug. Analogously, the passive docking unit is made up of the receiving cone with a recess for lock-on of the head of the pin of the active docking mechanism and the structural ring with the mechanism. When docking the spaceship with a station, the electrical plugs of the hydraulic lines are connected simultaneously.

After contraction of the structural rings the locks on the head of the pin are retracted and the rod part of the pin is pulled in. With this the backing process ends, and the process of checking the seal of the joint begins which is performed either by the crew of the docking manned spacecraft or from the ground (when docking a cargo spacecraft with the station). The seal is checked in two steps by the pressure stability: in the small cavity between two annular rubber seals (this cavity is first connected for a short period of time with the inside of the spacecraft and is thus purged), and then in the large cavity of the docking units (in the space between the rubber ring seals, the inside space of the cone and the surface of the pin).

In each of the units (passive and active) there is a hatch (with a system for locking and sealing it) for the crew to pass from the spacecraft into the station and back. The hatch includes a cover, the drive for opening and closing the cover and the seal drive (a pin is also installed in the cover of the active unit).

For undocking, the pressure is released from the large cavity, the drives of the peripheral locks disengage the latches and four spring pushers separate the spacecraft and the station. Undocking can be performed both by instruction from the spacecraft and by instruction from the station. In addition, there is a pyrotechnical undocking system.

System for Controlling the On-Board Complex (SUBK). This system makes it possible to control the station, its systems, instruments, units, scientific and experimental equipment both from the ground and by the crew. Simultaneously, the SUBK must provide for initial logical analysis with respect to the performance of certain operations of the inclusion of individual systems and instruments in the given developed situation (so-called analysis for the simplest requirements of noncontradictoriness). For example, the service propulsion engine cannot be switched on if the orientation system is not ready to operate, or it is impossible to actuate the gyroscopes if there is no report that the gyroscopes are wound.

The SUBK is made up of logical devices, commutators, program-timing units, control and display panels, and the instruments for connecting the electric power supply. The control instructions (to switch the individual systems, instruments, and so on on and off, to introduce conditions under which certain instruments or processes can be switched on) can be set from the ground (over the command radio link), from the station panels (by the crew), from the program-timing devices or from the operating systems (the so-called mutual control instructions).

The logical circuits of the SUBK receive these instructions, they check for noncontradictoriness with the processes going on at the station and they send out further execution commands. The program-timing devices permit automatic control of the station systems in the frequently recurring standard processes (communication sessions, preparation of orientation, the performance of corrections, and so on), insuring successive output of commands at given points in time. Here several parallel-operating programs included either from the panels or by the command radio link from the ground can be processed.

In order that the group be able to control the station and scientific equipment, there are control and display panels located at seven control stations. The control elements are command-signal devices (at station No 1), keyboards and control handles (orientation handles). The display and signalling of the execution of the commands and the parameters characterizing the operation of the systems and the station as a whole are insured on the electroluminscent display panels, the mnemonic circuits (for example, the program display on the main panel or the charging circuit on the control panel of the combined power plants) and the audio signal unit. All the control stations have the possibility of communications with the ground and over the internal intercom system with the crew members working at the other stations.

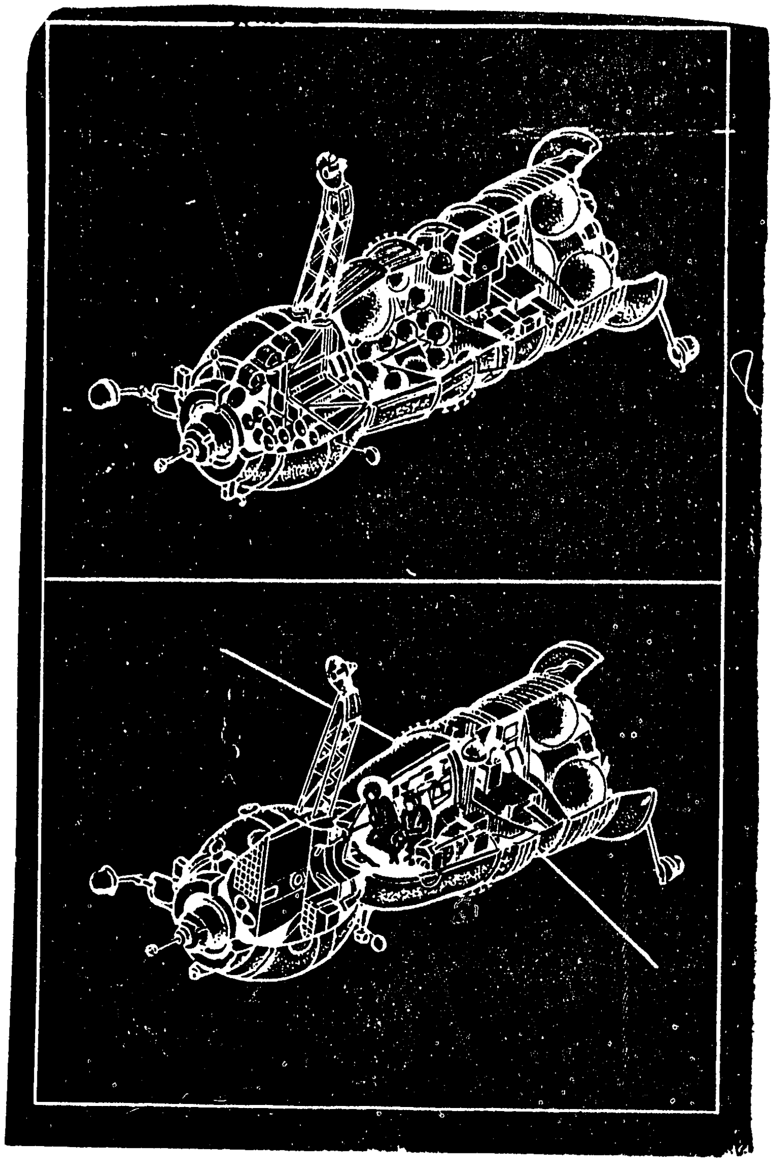
Scientific Equipment. The composition and the mission of the scientific equipment vary from one station to the next depending on the adopted program for the performance of the research and the development of operations during the course of the flight of the given station. The majority of scientific instruments have an output to the radio telemetric system for transmission of the measured parameters and the data characterizing their operation to the earth. As a rule, the instruments are equipped with control elements and means, means of monitoring their operation on the part of the crew. Much of the scientific equipment is delivered to the station in stages during the course of its flight.

Part of the scientific equipment is installed outside the sealed space of the station, and the rest, inside the sealed compartments. The thermal conditions of the instruments installed on the outside surfaces are insured by heat exchange of them with the thermostated hull of the station, vacuum shielded insulation and, in some cases, special covers that enclose the instrument from outer space when the given instrument is not in operation. The electric power supply for the scientific equipment, as a rule, comes from the single power supply system of the station. On the station provision is made for unused electric plugs ("rosettes") for connecting newly delivered equipment to the electric power. Part of the scientific equipment (as a rule, portable or with low electric power intake) has its own power supply in the form of batteries built into the instruments.

"Soyuz" Manned Transport Ships

At the present time the transport spacecraft has become the basic version of the "Soyuz" spacecraft, and it is almost not used at all on autonomous flights. As the transport spacecraft it must provide for insertion of the crew into orbit, rendezvous and docking with the orbital station, transfer of the crew on board, flight of the spacecraft as part of the orbital complex for a sufficiently prolonged period of time, separation from the station, descent of the crew to the ground with an acceptable level of G-loads for the cosmonauts when returning into the atmosphere, landing of the landing vehicle with acceptable level of G-loads acting on the cosmonauts during landing and also rescue of the crew in case of an emergency with the booster rocket during the phase of insertion of the spacecraft into orbit.

These problems are solved by joint operation on the on-board systems of the spacecraft and its structural peculiarities. In the structural design of the "Soyuz" spacecraft it is possible to isolate three basic parts: the landing vehicle, the instrument-service and the orbital modules. The landing vehicle is placed between the instrument-service and the orbital modules (see the outside back cover). With respect to its shape, the landing vehicle resembles an automobile light (see Fig 6). This shape was not



[Outside back cover]

selected accidentally. It provides for an aerodynamic lift (in addition to the force of frontal resistance) when the vehicle moves in the earth's atmosphere, which reduces the scattering of the landing points with respect to the given one and also decreases the G-load level when descending in the atmosphere.

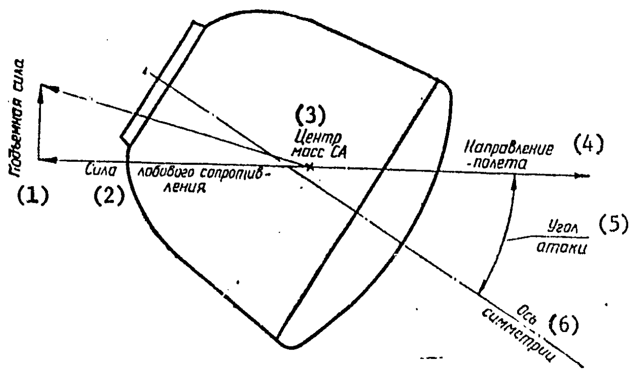


Figure 6. Shape of the landing module of the "Soyuz" spacecraft

Key:

1. Lift
2. Force of frontal resistance
3. Center of mass of the landing vehicle
4. Flight direction
5. Angle of attack
6. Axis of symmetry

On the "Vostok" spacecraft on which the landing vehicle was spherical in shape and naturally only had the force of frontal resistance, the scattering of the landing points reached 250 to 300 km. If an aerodynamic lift operates on the landing vehicle, then by controlling its vertical component, it is possible to control the trajectory of motion of the vehicle in the earth's atmosphere and, consequently, the range of this movement (regulating the "steeper"-"more gentle" trajectory). Even for small values of the aerodynamic quality[1] of the landing vehicle of the "Soyuz" spacecraft (0.2-0.3) the latter makes it possible to reduce the dispersion of the landing points to several tens of kilometers (and theoretically, to several kilometers).

If the lift is not used when the vehicle descends, this type of descent is called ballistic. The maximum G-loads during a ballistic descent depend

[1]The aerodynamic quality in aviation and cosmonautics refers to the ratio of the aerodynamic lift to the aerodynamic force of the drag.

on the steepness of the descent trajectory, but even for the most gentle trajectories the G-loads reach (as was the case with the landing vehicles of the "Vostok" and the "Voskhod" spacecraft) such values that the force acting at this time on the cosmonaut was 8 to 10 times more than his weight. Of course, this is an extremely undesirable phenomenon, especially when the crew is returning to the earth after a prolonged flight under conditions of weightlessness when even the ordinary earth's gravity is perceived by the cosmonaut's organism as a very heavy and unpleasant load.

The low aerodynamic quality of the landing vehicles of the "Soyuz" spacecraft lowers the maximum G-load when the vehicle moves in the atmosphere to values that correspond to the force under the effect on the cosmonauts exceeding their weight by only 3 to 4 times. This vehicle, which is an axisymmetric body, moves during its descent in the atmosphere with its blunt part forward. If the center of mass of the vehicle were located on the axis of symmetry, then no lift would occur. Therefore, the structural elements and the location of the equipment are selected so that the center of masses will be shifted relative to the axis of symmetry of the landing vehicle.

In order to control the range of movement, it is necessary to change the vertical component of the lift. This can be done either by varying the angle of attack as is done on aircraft (in our case it would be necessary to change the position of the center of masses, which appears to be quite difficult) or by changing the magnitude of the projection of the lift on the vertical plane as a result of controlling the bank of the vehicle. This procedure is also used on the "Soyuz" spacecraft.

The hull of the landing vehicle is protected on the outside by a heat protective coating which protects its structural elements, equipment and crew from the flow of incandescent gases surrounding the vehicle during its descent. Let us remember that the gas temperature in front of the heat shield reaches 10000°. On the lateral surface of the vehicle there are three windows. On one of them (in the middle) which during orbital orientation (when the longitudinal axis of the spacecraft is in the horizontal plane) "looks" downward to the earth, a viewer and orientation device is installed which is used by the crew for visual orientation with respect to the ground during manual control and for orientation during rendezvous.[1]

Inside the lander there are chairs for the crew, parachute systems, off-landing engines, a system for controlling the jet engines used to orient the vehicle during descent, the equipment and fittings for the spaces, life support systems, control systems, orientation systems, radio communications, direction finding, landing automation, and cargo return from the station

---

[1]During visual orientation with respect to the earth, the crew sees the horizon and the "travel" of the terrain under them by means of this instrment. It makes it possible to construct triaxial orientation. During rendezvous the given instrument operates like the periscope of a submarine, permitting the crew in the landing vehicle to see along the direction of the longitudinal axis of the spacecraft.

to the ground. In the upper constricted part of the landing vehicle there is a hatch through which the crew can transfer to the orbital compartment docked to the upper end frame of the landing vehicle.

In the orbital compartment is the equipment of the life support systems, part of the regular equipment, the docking automation, and the rendezvous equipment. The cargo delivered simultaneously with the crew to the orbital station is basically located here (part of the cargo is placed in the lander). In the upper part of the compartment (opposite the part of docking with the lander) is the active docking unit. Part of the rendezvous system antennas are installed on the outside surface of the compartment. The overall volume of the orbital module and the lander is about 10 m^3.

The instrument-service module includes the transfer frame, the instrument and service sections. In the transfer frame joining the instrument section to the lander part of the docking and orientation engines, fuel tanks, purging tanks, fittings, the small outside radiator of the STR system and the command radio link antenna are installed. In the instrument section is the basic instrument equipment providing for operation in the orbital phase of flight, but not required in the descent phase: before descent, the modules of the spacecraft are separated. The orbital and the instrument-service modules burn up in the atmosphere moving along the descent trajectory. The rendezvous-correction power plant of the spacecraft (with two engines), the docking and orientation engines, the large outside radiator of the STR system, part of the current sources of the electric power supply system of the spacecraft are installed in the service section. On the outer surfaces of the section are the sensors of the orientation and antenna system.

Before installing the spacecraft on the booster rocket it is covered by the nose cone. The engine of the emergency rescue system (SAS) is installed on the top of the nose cone. The nose cone carries out two missions: it protects the spacecraft from the effect of the flow of gas when the rocket is moving in the dense layers of the atmosphere and it separates the lander with the crew (by the operation of the SAS engine) in case of an emergency with the booster rocket in the dense layers of the atmosphere. During the normal course of insertion into orbit, after the rocket leaves the dense layers of the atmosphere, the SAS engine and the nose cone are jettisoned. After insertion into orbit when the engine of the last stage is switched off, the spacecraft is separated from the last stage.

All of the processes of orientation and control of the engines, the radio equipment, the operation of the life support system, the heat regulating system, the electric power supply, the descent and other systems are automated. This is done so that the spacecraft can fly without the participation of the crew in control. However, means of manual control are installed on the spacecraft which permit the crew if necessary to take control of the processes of all orientation, correction, rendezvous, and so on.

The orientation and motion control system (SOUD) of the "Soyuz" provides for orientation of the spacecraft in the automatic and manual modes, output of correcting pulses and the control of the rendezvous and docking processes. Its composition includes the sensitive elements (the infrared plotter of the local vertical, the ion sensors for orientation with respect to the velocity vector, the gyrosopic angle gauges and angular velocity gauges), the rendezvous radio system which provides for measuring the parameters of relative motion during rendezvous, the visual orientation instruments (optical and television), the calculating and commutation instruments, the manual control and display elements. The SOUD solves its problems, operating jointly with the systems of jet control engines for docking and orientation and with the rendezvous-correction power plant.

The most complicated operating mode of the SOUD is the rendezvous process. Before insertion of the "Soyuz" transport spacecraft, the station is located, as a rule, in the operating orbit with an altitude of about 350 km. The transport spacecraft is inserted into orbit when the plane of the station orbit passes through the launch site, and the station has just passed over the launch regions. The spacecraft is inserted into an intermediate orbit with minimum altitude on the order of 190 to 200 km and maximum altitude on the order of 250-270 km. The direction of flight of the booster rocket of the transport spacecraft (that is, the plane of its trajectory) is selected so that the spacecraft will fly in the same plane as the station after insertion. The launch time is selected so that after insertion of the spacecraft it will be approximately 10,000 km behind the station.

Inasmuch as the altitude of the spacecraft orbit is less than the altitude of the station orbit, the period of its rotation around the earth is less than the period of rotation of the station, that is, the "Soyuz" moves faster relative to the earth and, consequently, gradually overtakes the station along the orbit. In order to equalize the altitudes of the spacecraft and station and for them to rendezvous at a previously selected time, several corrections (up to four) are made in the orbit of the transport spacecraft. When the spacing between the spacecraft and the station becomes less than 25 km, the rendezvous radio equipment is switched on by the command given by the automation on the spacecraft and on the station. Then the exchange of radio signals begins, the direction is determined in which the desired object is located, and mutual orientation of the spacecraft and the station begins so that the docking unit of the station planned for docking "sees" the spacecraft, and the docking unit of the spacecraft sees the station.

Then the rendezvous radio equipment transmits electrical signals to the calculator proportional to the angles of the direction of the station (the line of sight) in the coordinates system of the spacecraft, the angular velocity of the line of sight, the range to the station and its rate of variation. By the parameters of relative motion obtained, the computer determines in what directions (for acceleration, braking or in the lateral direction) it is necessary to output the thrust of the service propulsion engine on the spacecraft for rendezvous; then the instructions are given and the direct orientation and turning of the spacecraft realized, the engine is switched on and off. All of this is done so that the speeds of relative motion perpendicular to the line of sight will be "extinguished," and the radial velocity will insure gradual rendezvous of the spacecraft with the station.

On approaching the station the speed of the spacecraft decreases. This process -- automatic rendezvous -- continues to a distance of 200-300 meters between the spacecraft and the station at which the conversion to the docking mode is made. In this mode the spacecraft is already permanently directed with its docking unit in the direction of the station, and the control of the motion of its center of masses is caused by the operation of the coordinate jet engines. They provide for output of the required pulses both along the longitudinal axis of the ship (for acceleration and braking) and in two other perpendicular directions (provisionally "up"-"down" and "right"-"left"). The latter process can continue in the automatic mode until docking.

Theoretically the crew can take control of the docking in its hands (controlling the attitude of the spacecraft and switching on the coordinate engines) and complete docking under manual control. In order to provide the possibility of manual control of docking and in order to monitor the process taking place automatically, the spacecraft and station crews are given information about the rendezvous parameters, the operation of the engine and fuel consumption. Simultaneously, with the help of television cameras (on the station and on the spacecraft) and an optical orientation viewer, the crew observes the station (or the spacecraft respectively), its motion and orientation.

The SOUD makes it possible to control the "Soyuz" spacecraft to mechanical contact of the docking units, insuring the parameters of relative motion required for response of the docking unit.

The rendezvous-correction power plant (SKDU) puts out thrust pulses required for rendezvous, correction of the orbit or for transfer of the spaceship from orbit to descent trajectory on command from the SOUD automation or from the control panel. The composition of the power plant includes two engines with a thrust of more than 400 kg each, the pneumohydraulic automation, fuel tanks and purging tanks (to provide for forcing the fuel out of the tanks and feeding it to the engines). In order that the purging gas not mix with the fuel under weightlessness conditions, there are elastic gas and liquid separators inside the tanks (so-called bags) made of organic film.

The system of orientation servoelements (SIO) provides for the creation of controlling pulses for orientation of the spacecraft, for stabilization of it during operation of the rendezvous-correction power plant, for turning during the rendezvous process and for coordinate displacements during rendezvous. The SIO system includes 14 docking and orientation engines with a thrust of about 10 kg-force each, 8 orientation engines with a thrust of approximately 1 kg-force each, fuel tanks, purging tanks, and the pneumohydraulic automation.

The launch control system (SUS) correspondingly controls the movement of the lander of the "Soyuz" spacecraft when it descends from orbit to the earth. The SUS includes the hydraulic angle and angular velocity gauges, the G-load gauges, and the computers. The SUS provides for stabilization of the lander and as a result of controlling the attitude with respect to bank, regulates the vertical component of the lift which permits regulation of the descent range.

The system of descent servoelements operates on the instructions of the SUS, providing for the creation of control movements required for turning and stabilizing the lander. The system elements are basically located outside the sealed volume of the lander, but under the heat shield. The system includes 6 control engines with a thrust of up to 15 kg-force each, the fuel tanks, the purging tank and automation.

The landing system of the lander operates in the final phase of the descent of the spacecraft. On entry of the spacecraft into the atmosphere, it has a velocity of about 7.8 km/sec. As a result of braking in the earth's atmosphere, its velocity gradually diminishes (to subsonic) and at an altitude on the order of 12 km it is on the order of 240 m/sec. As a result of the operation of this system, the velocity of the lander is extinguished to an amount insuring safe landing of it.

The given problem is solved by the joint operation of parachute systems, the soft landing engines, the automation and the shock absorbers of the chairs in which the crew is seated during landing. The automation provides for the giving of instructions at the given altitude to introduce the basic parachute system and also the reserve parachute system if the basic one does not respond), for the preparatory operations before landing, for switching on the soft landing engines directly before the ground surface.

The parachute systems are installed in two individual sealed containers covered with covers.

The electric power supply system (SEP) is made up of the automation and chemical storage batteries. The electric power supply of the on-board systems of the "Soyuz" spacecraft after docking with the station is realized from the station electric power supply system. The storage batteries are simultaneously recharged from the SEP of the station. The connection of the electric power supply system of the spacecraft to the station is realized through the electric power plugs installed in both docking units and connected on contraction of the structural rings.

The heat regulating system of the spacecraft (STR) maintains the temperature and air humidity required for the crew in the lander and in the orbital module and also the thermal conditions of the instruments in the instrument compartment; it realizes thermostating of the unsealed service module, the fuel lines of the system of servoelements. The STR of the "Soyuz" includes the corresponding automation, the cooler-driers, the gas-liquid heat exchangers, two liquid circuits (the circuit of the crew compartments and the circuit of the outside radiator) with pumps that circulate the liquid, regulator cocks and the compensators. Both circuits are connected through the liquid-liquid heat exchanger.

The heat released in the compartments is transferred by means of the heat exchangers to the liquid circulating in the compartment circuit. This liquid is then pumped through the tubes welded to the hull of the service module, providing for thermostating of it. The heat from the liquid is transferred (through the liquid-liquid heat exchanger) to the liquid cooling agent of the circuit of the outer radiator; by means of this circuit it is removed to the radiator from which it is radiated into outer space. The automation and the regulators permit regulation of the liquid temperature in the compartment circuit and, consequently, the wall temperature of the radiator of the cooler-drier (and the moisture level respectively) and the air temperature in the compartments.

In addition to the two basic loops of the STR there is an auxiliary loop which after docking with the station provides for the transfer of heat from the station to the loop of the crew compartments. All of the surfaces of the spacecraft not occupied by antennas, engines and sensitive elements and also the surface of the hull under the STR radiators are covered with packets of vacuum shielded insulation.

The life support systems (SOZh) of the crew on the spacecraft theoretically perform the same functions as the analogous means on the station. The difference consists primarily in the fact that the reserves placed in the spacecraft are designed only for a few days. In addition, the composition of the spacecraft SOZh life support means includes spacesuits with the on-board gas supply system and automation, the heat shielded suits and also means which can be used in case of an emergency landing in an unpopulated area.

After docking of the spacecraft with the station its SOZh, providing for regeneration of the air in the crew compartments are switched off. An air duct is run from the station through the open hatch through which air is fed into the crew compartments from the station. This insures the required composition of the spacecraft atmosphere, the degree of humidity and elimination of harmful gas impurities from the compartments of the spacecraft.

Before undocking the spacecraft from the station the air duct is retracted, the hatches in both of the docking units are closed, the regenerators, absorbers and cooler-driers are switched on in the spacecraft.

The radio equipment of the "Soyuz" spacecraft provides for radio telephone communications between the crew and the earth in the ultrashortwave and shortwave bands, the transmission of television images to the earth from the inner and outer television cameras, telemetric information, orbital monitoring, the reception of control commands on board. The telephone communications with the flight control center, the transmission of commands and digital data on board the spacecraft and reception of information from on board the spacecraft are realized using land and floating (on maritime ships) measuring and control stations when the spacecraft is in sight of them. The communications with the spacecraft are maintained in practice on all of its orbits: during each orbit of the spacecraft around the earth, as a rule, it is possible to maintain communications with the spacecraft from several minutes to tens of minutes.

If continuous telemetric monitoring is needed (for example, when realizing maneuvers), the on-board telemetric memories are switched on. They store the information which is transmitted later over the ground stations.

The on-board complex control system (SUBK) of the spacecraft is used for control of the operation of the on-board system and coordination of their operation both in the automatic control mode (from the program-timing devices and by the instructions transmitted over the radio linkup from the earth) and in the lateral control mode (by the crew). The SUBK of the "Soyuz" includes the logical devices, commutators, the electrical automation (for connecting the electric power supply of the instruments and systems), the control panel and the command signal devices.

Combination control is realized in practice during the entire flight of the spacecraft. The control procedure varies as a function of the required flexibility of the operations of the given time, the available time, and so on. Therefore, part of the control commands come directly from the earth (with the command radio link), part from the program-timing devices and part are issued by the crew through the command-signal devices or from the panel (on request from the earth).

The crew usually works for about 24 hours on the spacecraft. After insertion into orbit and checkout of the seal on the crew compartments the cosmonauts enter the orbital module and remove their spacesuits. On the first orbits of the spacecraft around the earth, the on-board equipment is checked out along with the basic dynamic operating conditions of the spacecraft (attitude, turning, testing of the rendezvous equipment, advancement of the rod of the docking unit); the first two corrections are made to the spacecraft orbit. The next day, one or two more orbital corrections, rendezvous and docking of the spacecraft with the station are realized.

After docking and checking the seal of the connection of the structural rings of the spacecraft and the station the crew opens up the transfer hatches of both the docking units, moves into the station and begins work there. The buffered batteries on the spacecraft are recharged, the electric power supply buses of the on-board systems of the spacecraft are disconnected from their own electric power supply and are connected to the station system. Periodically the condition of the spacecraft is checked from the ground by telemetry and by the crew from the control panel. In addition, the spacecraft is always kept ready to separate from the station and descend if necessary.

When executing a long-term expedition on the station during its flight, the spacecraft of the basic expedition is replaced by the spacecraft of the next expedition. After completion of the work on the station several days before descent the crew mothballs the station, transfers the equipment to the lander which must be delivered to the earth. Several orbits before the descent the cosmonauts move to the spacecraft, close the hatches, check out the seal, and the ship is separated from the station. Usually descent is made in central Kazakhstan.

"Progress" Cargo Transport Ships

The purpose of the cargo spaceships is to deliver dry cargo, water and fuel to the orbital complex. The "Progress" is built on the basis of the structural design and on-board systems of the "Soyuz" spacecraft (see the back cover). Its principal differences from the "Soyuz" spacecraft are connected with the fact that it must operate in the automatic version and is not designed to return to the earth. Theoretically it would be possible to build a multiple-use manned cargo spacecraft, but a significantly more powerful booster rocket (which consequently would be more expensive) would be required to insert it into orbit.

This is easy to understand in the example of the "Soyuz" spacecraft. Out of the entire spacecraft assembly, only the lander weighing less than half the weight of the spacecraft is returned to the earth. When the spacecraft flies with crew it can take with it only a few tens of kilograms of cargo. In order to deliver 2 to 2.5 tons of cargo, it is necessary to increase the weight of the spacecraft by 2.5 to 3.0 tons (considering the structure). If we wished to make the spacecraft a multiuse vehicle, then we would have to join all of its modules into a single unit and enclose it in thermal shielding. Then the weight of the spacecraft would be increased by 1.5 to 2 times and, consequently, for insertion of it a booster rocket would be needed of almost the same power as the booster rocket of the station.

If we are talking about an economically effective earth-orbit-earth transport system, then it appears expedient to build a fully multiple use complex, not only the spaceship, but also the booster rocket. However, for the solution of this problem significantly more time is required. Therefore, when designing the "Progress" spacecraft the decision was made to make it single-use and to utilize the booster rocket of the "Soyuz" spacecraft to insert it.

The cargo spacecraft is made up of three modules: the instrument-service module, the refueling component module and the cargo bay. In the cargo bay the scientific equipment, the equipment required to perform the preventive repair work, the reserves for the life support means (regenerators, absorbers, food, water, clothing and so on) are delivered. The hull of the compartment is welded from two spherical halfshells and with a cylindrical insert between them. The bay is installed with one side (the lower side) on the supporting frame (of the compartment) for the refueling components. In the upper part of the compartment is an autonomous docking unit (the pin type) with transfer hatch permitting the station crew to enter the cargo bay after docking the cargo spacecraft with the station and move the delivered equipment to the station (the transport cargo ship is docked on the service module side of the station -- to the intermediate chamber).

In contrast to the docking unit of a manned spacecraft, two hydraulic plugs are installed on the cargo unit which are mated with the corresponding plugs in the docking unit of the intermediate chamber. The station is refueled with oxidizing agent and combustible fuel component through the plugs. Inside the cargo bay is ordinary air at normal atmospheric pressure. The size of this bay is about 6.6 m^3. Up to 1300-1400 kg of equipment must be placed in it. The awkward equipment (such as regenerators, and so on) is attached directly to the supporting frame of the bay; the light equipment and small instruments are placed in containers.

After transferring the delivered cargo on board the station before undocking the spacecraft the crew transfers the spent equipment (such as the regenerators, absorbers, and so on), the replaced failed instruments, containers with waste appearing during this time (in order to not use the locks one time), used linens and so on to the free space in the cargo bay. The size of the station is limited and, if this is not constantly done, it would become jammed.

In the compartment for the refueling components there are two modules with the combustible component of the fuel (asymmetric dimethyl hydrazine), two tanks with oxidizing agent (nitrogen tetroxide), tanks with compressed air (for purging the station) and nitrogen (for purging the tanks with fuel or transferring it to the combined power plant of the station), the pneumo-hydraulic automation (pressure reducers, valves, gauges and so on).

The components placed in the tanks are chemically aggressive and poisonous to man, and therefore any contact of their vapor (for example, in case of loss of seal of the tanks, the lines, and so on) with the crew quarters is inadmissible, and consequently, any contact with the cargo bay is inadmissible. The compartment for the refueling components is unsealed; the lines running to the fueling plugs in the docking unit are also laid along the outside surface. Analogously, the lines running from the fueling plugs of the station to the tanks from the combined power plant are laid outside the intermediate chamber in the unsealed service module. The hull of the compartments of the refueling components is thermostated as a result of pumping the liquid from the inside circuit of the STR through pipes welded to the skin of the compartment.

The instrument-service module is similar with respect to structural design and composition of the equipment placed in it to the analogous module and the "Soyuz" spacecraft. The instrument part of the module, the size of which is doubled as a result of introducing a cylindrial insert, differs noticeably. The equipment for controlling the refueling and that part of the radio equipment which was placed in the orbital module and the "Soyuz" spacecraft are placed in the additional space.

On the outer surfaces of the spacecraft antennas are installed for the radio complex along with sensitive elements: two infrared local vertical plotters instead of one and the "Soyuz" spacecraft), ion direction plotters for the velocity vector and also the control jet engines. The installation of a second infrared local vertical plotter is connected with the fact that on the unmanned spacecraft it is necessary to increase the reliability of the automatic orientation system. The sensor which provides for constructing the local vertical operates in the infrared part of the spectrum. This choice is explained by the fact that in the case of using a sensor operating in the visible part of the spectrum, it could not provide for orientation of the spacecraft in the shadow of the earth. The sensor operating on the reception of thermal radiation "distinguishes" the earth and the horizon from outer space well both over the illuminated and over the shadow side of the earth.

Three color indexes and television cameras are installed in the vicinity of the docking unit. They permit visual monitoring of the process of approach of the cargo spacecraft to the station (including in the shadow of the earth): from the earth by the television image of the spacecraft (using the television cameras of the station) or from the station (via the television cameras of the spacecraft). In addition to the visual monitoring, the crew (on the station panel) and the personnel of the flight control center monitor (on the displays) the parameters of the relative motion (range, radio velocity, angular velocity, line of sight), the operation of the engines and automation. The data on the course of the rendezvous process are transmitted to the earth using the radio telemetric system.

Before refueling, the compressors pump out the gas into the purging tanks from the gas cavities of the tanks for the combined power plant which must be refilled. The automation of the refueling system provides for checking the seal of the connected hydraulic plugs of the refueling lines. On instruction from the crew from the refueling panel or from the earth, the tanks are purged with the components in the cargo spacecraft, the valves connecting these tanks and the tanks of the combined power plant to the refueling lines are opened, and the fuel is transferred. The refueling is realized in turn in each separate tank. After completion of refueling, the valves joining the tanks to the refueling lines are closed, and this line is opened to outer space and purged. This operation is realized so that when undocking the remains of the components will not get on the surfaces of the docking units.[1]

Role of Automation and Man on Board the Orbital Complex

The basic control functions both on the spacecraft and on the orbital stations, just as in any complex complexes are coordination and monitoring of the operation of the on-board equipment, switching of the on-board systems to various operating modes, regulation of the adopted mode, analysis of the condition in the operation of the on-board systems and the structural elements, and if necessary, the introduction of the redundant equipment.

Now means have been created for almost completely automating the control on board and providing (in the presence of communications with the earth and output of control instructions from the ground) the possibility of spacecraft and station flight in the automatic mode. The monitoring and the analysis of the condition of the spacecraft or the station is in this case realized by telemetry on the ground by a collective of specialists using the automated means of processing telemetric and trajectory data. If these means had not been created, it would be impossible to operate automatic repeaters, meteorological satellites, automatic interplanetary stations and probes.

But what does man then have to do on the station?

With time the answers to this question will change. According to the concepts of today it is possible to mention three groups of problems which the crew must solve in flight. The first group is connected with providing for operating reliability and safety of the crew itself. Inasmuch as the direct monitoring of the process is taking place on the station it is now possible only in the zone of radio visibility of the ground command-measuring stations, and the station is in this zone of radio visibility no more than 20 to 30% of the total flight time, it is considered necessary that all complex processes which take place at least partially outside the zone of radio visibility of the ground stations be conducted under the crew monitoring, and the especially important processes, under simultaneous dual control -- from the ground and by the crew.[2]

---

[1]For more detail on the technical characteristics of the "Progress" cargo spacecraft, see K. P. Feoktistov,"'Salyut-6' Orbital Station," SOVREMENNYYE DOSTIZHENIYA KOSMONAVTIKI [Modern Achievements of Cosmonautics], Moscow, Znaniye, 1978.

[2]The monitoring on the part of the crew provides for examination of the information on the functioning of the on-board systems which is output to the control panel, analysis of this information, comparison with the picture expected in the given process and estimation of the correctness of operation of the on-board equipment.

The same group of problems includes the possibility (by the results of the analysis or by recommendation from the earth) of taking on the control of the operations in case inadmissible or alarming deviations are noted during the automatic process. For example, on the "Soyuz" spacecraft the crew can take on the control of the attitude and stabilization, switch the correction engine on and off, control the rendezvous process "manually," switch equipment on and off, and so on.

In the given case the man on board performs the functions of a redundant logical computing and control unit which is simultaneously a "sensitive element" (visual orientation -- determination of position in space). Man can perform many such functions even on the "Salyut" stations. Acting as a redundant system, man improves the reliability of the orbital complex and the flight safety. According to modern concepts, the redundancy of vitally important automatic systems is a mandatory function of man on a spacecraft.

The second group of problems is connected with the preventive repair, adjustment and other operations of servicing the station. These include repair or replacement of instruments and units which have failed or have clearly exhausted their reserves, transfer of the delivered equipment from the cargo spacecraft to the station, installation of it, correction on board and checkout of the operation, adjustment and tuning, cleaning the station, and ejecting waste through the locks. This group of problems includes the operations in which it is difficult to replace man.

Each of these operations is quite simple and elementary and is described quite simply by natural language: "Take block H, place it behind panel M in position B, connect plugs A, B, C, ... on the block to plugs A^1, B^1, C^1, ... of the on-board cable network and by instruction K check out the correctness of the connection and then the operation of the device." However, for each instrument there is characteristic information which is different every time, and for each specific instruction (for example, "take block H") an entire series of problems come up.

Actually there are no standard, easily algorithmized operations. Such operations can be realized without the participation of man only after building robots which will be slightly inferior to man, but can have large memory, powerful computers, outside information receivers and servoelements ("hands," means of displacement). From the point of view of the engineer, man is a type of complex machine. Even for the realization of the simplest operations such as seeing the objects and the environment, the human brain completes an enormous number of operations permitting the construction of the viewed picture in his consciousness (and not on the retina of the eye!).

The fact is that the human eye, and head are constantly moving and rotating. Therefore, the eye as an optical system provides for the construction of a constantly moving picture on the retina, for as a result of movement of the eye and head, and so on different parts of the image reach each given element of the retina, changing constantly. At the same time we perceive the outer world as stable, easily distinguishing moving objects from stationary ones.

This is a consequence of the fact that a defined part of the human brain, operating as a special computer, uses the information from each point of the retina, information about the position of the eye, the head, and so on, previously stored information about the preceding position of the objects. The signals received are "recalculated" to a stationary coordinate system (with respect to any reference points in the field of view), where the image is constructed. It is possible that the process of recognition of the object is no less complex. For the solution of such problems obviously it is necessary to build miniature processes with billions of elementary computing elements.

The third group of problems includes the operations directly connected with realizing scientific research and experiments. If we analyze each separate research and experiment problem, then almost every time we can find the possibility for easy automation of the process. For example, let us consider the astrophysical observations performed using any telescope. In this case it is possible to represent the sequence of operations as follows:

Orient the station so that the axis of the telescope will see a given point of the sky, and then maintain this attitude;

Prepare the telescope, its electronic modules and receivers for operation, that is, perform a number of successive operations with respect to inclusion of a defined sequence of modes, turn on the power supply, wind the gyroscopes or compressors and cooling units, connect the astroguides, their drives and so on;

Prepare to switch on and switch off the system for recording the measured parameters and monitoring the operation of the supporting systems;

Switch on the telescope, take the measurements and record them;

Reorient the station on a new source and again make the recording, and so on until the end of the series of observations.

It is obvious that all of these operations are usually algorithmized,[1] and the possibility of the automation of this process, including the performance of the adjustment, target selection, exposure time, and so on is unquestioned. The same thing can be said of such operations as photography, technological and biological experiments. It is true that here certain complications arise: the simple processes of reloading the cassettes, recharging the process heaters, and the thermostats are automated at the expensive price of significant complications, for example, making a judgment such as

---

[1]By algorithmization here we mean the description by words or equations or the logical conditions of all the operations making up the functioning of the given machine or process and which must be performed to solve the problem of the given observations or experiments.

"Is it worthwhile to take photographs: are there too many clouds" in the automatic mode is extremely difficult.

It must be noted that other factors also come into play -- the fact of the presence of a man on the station. If it is known in advance that there will be a man on the station, then why complicate the equipment many times (for example, solving the problem of multiple reloading of the camera) and lower the reliability of the performance of the experiments at the same time? Here man can easily adjust the equipment, install the capsule in the heating element, select the required fusion load from the panel, and so on. Some of these operations -- adjustment, tuning, altering the measurement program -- will be desirable to leave to man even in the future.

However,all of this leads to the fact that man on a station turns out to be involved in too large and varied a circle of operations. On the one hand, this leads to overload, and on the other hand, to reduction of the efficiency of the entire complex inasmuch as by comparison with machines, the man on the station has definite deficiencies. He must spend time sleeping (9 hours is the norm now adopted on the "Salyut" stations), physical exercise (2.5 hours is the required amount for weightlessness prophylaxis), for breakfast, lunch and dinner (a minimum of 2 hours, considering the time preparing the "trapese"), rest (1 to 1.5 hours is the so-called "personal time"), communications with the ground (1 to 1.5 hours a day) and medical monitoring (about 1 hour).

Thus, the time which he can spend on purposeful work is a total of a few hours a day. Indeed, it is also necessary to consider 2 days off a week, medical checkup days, days for service operations (correction, docking, undocking, mothballing, unmothballing, transferring cargo, refueling, and so on). All of this leads to the fact that the time allocated for the performance of research and experiments is decreased, and the time efficiency of the manned station turns out to be low.

How do we get out of this situation?

In the case of solving the problems of the first group it is obvious that it is necessary to strive for complete relief of man from the functions of monitoring and controlling on-board equipment, the function of analyzing its condition. However, this, of course, is realizable only under the condition of performing the required measures with respect to increasing the operating reliability and providing for monitoring and analysis of the condition of the complex without the participation of the crew. The resolution of the given problem is possible in two ways and obviously one and the other will be used at some time.

The first way is to provide for the functions of controlling the on-board equipment, monitoring and analyzing the condition as a ground service which is possible only in the case of providing in practice continuous radio communications between the earth and the orbital complex. This can be achieved either by uniform placement of a sufficiently large number of command-measuring stations (on the order of 200 to 300 stations) connected by communication channels with the flight control center on the continents and oceans or by using a system of relay satellites for direct communications with the station located in stationary orbit (as, for example, was realized during the joint flight of the "Apollo" and "Soyuz" spacecraft in 1975).

On the modern level of engineering, the control and communications through the radio relays are entirely realistic and realizable. It is entirely possible to insure in practice continuous operative monitoring and analysis of the condition of the orbital complex and the processes on it from the ground, to output the required commands to the systems and units at the required times. This makes it possible to carry out active complex processes even while the cosmonauts are sleeping or resting, performing physical exercises, and so on.

The deficiencies of this method are insufficient autonomy of the station, the necessity for continuous involvement with the given station on the part of the specialists at the flight control center, the ground communication stations through the satellite relays, loading of the radio relays themselves with the transmission of "raw" (unprocessed) data. As the number of stations and spacecraft in orbit increases, this method becomes clearly unacceptable and in the future obviously it will be necessary to be oriented toward the other method.

The second method provides for the installation of powerful and reliable on-board computers on the complex capable of processing and analyzing the results of measuring the parameters characterizing the operation and the condition of the complex and its on-board systems. The possibility of algorithmization of the processing and analysis of the condition is entirely obvious. Usually this is realized by comparison of the measured value with its weighted value (and tolerance interval) or with a graph of its variation, and then by a set of parameters the algorithms are defined: "taken altogether, is everything in order or not?" and "where is the admissible deviation?." These processing and analysis algorithms are already being executed on the ground computers.

For execution of the second method it is necessary to create a complex of miniaturized on-board computers which can solve analogous problems on board the station.

However, the first and second procedures for solving the problems of reliability and safety will not exclude the possibility that in the case of occurrence of a dangerous situation the crew can take control. However, as a rule, the station crew should not be occupied with such problems.

Approximately the same thing must be said of the third group of problems pertaining to the performance of research and observations: everything that can be automated without great effort must be automated. First, a large number of experiments and observations are left to man here (for example, visual observations), which it is unprofitable to automate. As for the second group of problems of man, the problems with respect to servicing the station equipment (tuning, adjustment, transfer, installation, connection of the equipment, and so on), obviously this area will be left to man for a long time to come.

The main problems of man on the orbital complex are readiness to accept new and unexpected information and data, to process it and the capability for making an unprogrammed decision required at the given time. The discussion of the role of automation and man on the station used the example of the orbital complex here, but if such an investigation were carried out in the example of specialized stations we would come to the same conclusions: man must not perform primitive or easily automated work. He must do what is difficult to automate, in particular, he must provide for the reception of new, unprogrammed information, repairs, adjustments, tuning, alteration of the work program, and so on.

Prospects for the Development of Orbital Complexes

A more general problem is connected with the resolution of the "man-automation" problem. This more general problem is the future of orbital complexes. It is necessary to consider that there are hardly "clear skies" ahead for manned orbital scientific complexes. Life presents a number of theoretical problems, the main one of which is the place of man in orbit, the required degree of direct human participation in space work.

At the present time there are proponents of active participation of man, and there are opponents. It is difficult to say which there are more of. The proponents of direct participation of man in work in orbit, in addition to logical arguments, rest their case involuntarily on the natural effort of man to expand the sphere of his life and activity, to go beyond previously reached limits, that is, to penetrate into an area that is new to him. This is one of the profound natural peculiarities of man -- the eternal striving for something new, curiosity, a striving for self-affirmation.

The opponents of broad participation of man in space operations use more specific and, at first glance, more weighty arguments -- economy and safety. The proponents of the use of basically automated equipment begin with the theoretically correct position: if we make specialized space vehicles, they can easily be made completely automated. As has already been stated, the problems of control, orientation, astrophysical research, photographing the earth and so on are algorithmized and, consequently, can be solved with the help of "automata."

Obviously, the solution of defined problems in cosmonautics using automata is significantly cheaper than with the use of man. Actually, the automaton can operate around the clock (and not a few hours a day) and without days off. In addition, there are expenses connected with the manufacture and launching of manned spacecraft for delivery of man to the "work area" and for returning him to the earth or expenses on maintaining the required conditions for man to work and live in the orbital spacecraft (the corresponding sealed spaces, means of rest and weightlessness prophylaxis, oxygen, water, food, and so on).

However, in favor of the use of man it is possible to present arguments regarding the reliability of the solution of the problems in cosmonautics: man on board a spacecraft can not only take control in a difficult moment, but, the main thing, he can replace an instrument that has failed or repair it, eliminating the failure. Actually, during the flight of the "Salyut-4" station and especially during the flight of the "Salyut-6" station the advantages connected with the presence of man are clearly demonstrated. For example, at the very beginning of the flight of the third basic expedition on the "Salyut-6" preventive repair work was done to free one of the fuel tanks of the combined power plant, replace the headset assembly and the radio telephone communication system and the television modules, install a television receiver and replace one of the radio transmitters, repair the video tape recorder and install an additional bank of storage batteries, and so on.

Such operations make it possible to cover the "bottlenecks" in the reserves of the on-board systems and thus increase the work time and use of the spacecraft. It is true that to these arguments the proponents of the use of automata answer that now it has been proven possible to build reliable automata which are capable of operating without failure, performing their missions for several years. These include communications satellites (there are many examples of their operations for 2 to 3 years), the automatic interplanetary station-probes (for example, the first flights to Jupiter took about 5 years), meteorological satellites and many others. It has been stated (and theoretically correctly) that by creating new electroradio instruments and units with an operating reserve on the order of 5 to 10 years by using deep redundancy it is possible to insure the operation of automatic equipment for, let us say, 10 years. And more, if necessary, inasmuch as in 10 years at the present time almost any machine becomes obsolete and must be replaced by a new, improved one.

How do we analyze these contradictory arguments, each of which is unquestioned? First, it is possible to state that in this sense man has a "solid" beachhead -- the orbital multipurpose space laboratory. Now the presence of man on board the complex offers maximum possibilities with respect to performing the most varied experiments, and his presence makes it possible to expand or change the experiment program in flight.

In addition, many operations simply cannot be performed without the participation of man. These include the visual observations, the development of life support means, the biological studies. All of them are required for interplanetary flights and for prolonged work of man in outer space, studies of the possibilities for man to live and work for a long time under space flight conditions.

However, the scientific orbital complexes are only the beginning of active human activity in space. It is difficult to imagine that having the theoretical possibility of building interplanetary spacecraft mankind will not use it and will not send interplanetary expeditions for deeper studies of the planets of the solar system.

However, obviously this is not the primary direction of the future activity of man in space. It appears possible in the near future to develop industrial activity -- the creation of industrial projects in orbit. The technological experiments performed at the present time indicate that perhaps it will be expedient to organize industrial production of unique materials, superpure crystals, optical materials and biological preparations in orbit. This production will be automated to the maximum. However, in any case it is necessary to adjust the equipment, provide for the delivery of raw material and the return of the final product and to develop the process lines. All of this is difficult to imagine without the participation of man.

There is another possibility connected with the necessity of human participation -- the creation of electric power plants in orbit to supply the earth with electric power. This problem is attracting the attention of the engineers and scientists of various countries. Considering the limited nature of the fuel resources of the earth, the more and more acute problem of atmospheric pollution on the part of thermal power plants, the dangers connected with pollution of the natural environment for widespread development of nuclear power engineering (especially in case of emergencies), it appears expedient to investigate the possibility of obtaining electric power using solar orbital electric power plants with a capacity of several millions of kilowatts.

Such an electric power plant in stationary orbit would have to include devices for collecting solar power and converting it to electrical power, devices for converting electric power to radiation and microwave band and transmission of the energy to the earth (by a radio link) using a highly directional antenna, by means of orienting the energy collectors on the sun and the transmitting antenna on a given point on the surface of the earth where the energy of the radio emission will be received and converted to electric power.

The estimates show that the weight of such an electric power plant will be on the order of 100,000 tons, and the diameter of the transmitting antenna, on the order of 1 km! From these figures it is clear that there are enormous difficulties on the path of creating such an electric power plant. The cost of delivering the cargo into orbit (let us remember that we are talking about stationary orbit), the installation of the station in orbit and the cost of intermediate products have great significance.

If we provisionally assume approximately equal distribution of the expenditures on these three basic items, then in order for such power production to be profitable, the cost of delivery of one station into orbit must be about 50 rubles per kilogram. It must be said that modern means of delivering in orbit and cost of equipment (for example, cost of a kilogram of solar cells) are many times more expensive. For example, the planned cost of delivery of equipment using the American multiple-use transport system will be about 350 to 500 dollars per kilogram. Thus, in order to solve this problem it is necessary to reduce the cost of delivery by at least an order and to provide the possibility of creating a giant flow of cargo into orbit. If we are talking about solar orbital electric power plants, then their creation will be meaningful only if they can make a significant contribution to terrestrial power engineering.

At the present time the power of the ground electric power plants is about 1 billion kilowatts. Considering that the creation of orbital electric power plants will be possible no sooner than the year 2000 and considering the total power of such stations will also be on the order of 1 billion kilowatts, the delivery of the equipment and elements of the electric power plants into the installation orbit for further assembly will require 500,000 flights of such spacecraft as the presently developed American "Space Shuttle" transport vehicles. If we assume that this program will take 25 to 50 years, then it is necessary to realize 10,000 to 20,000 launches per year.

It is quite obvious that for the execution of the program for solar orbital electric power plants it will be necessary to create other transport systems capable of delivering 200 to 400 tons in orbit in one flight with a delivery cost of the cargo into orbit 10 to 20 times cheaper than using the Space Shuttle. Even in the presence of a space fleet of 50 to 100 such prospective transport ships, the introduction of one or two orbital electric power plants into operation per year will make it necessary to realize about 20 launches of these ships per year.

In addition, along with the delivery of the required equipment and the structural elements for the electric power plants into the installation orbit it is necessary to assemble them, deliver assembled stations or parts of them into stationary orbit. Of course, in order to perform all of these operations it is necessary to create automated plants in orbit which will produce girders, battery panels, the elements of radio antennas, and so on from the intermediate products delivered from the earth (for example, strips for welding the tubes of the future girders).

However, for the performance of such operations not only automated plants, mechanisms, and so on are required, but also personnel who will control the production process and realize the installation of orbital electric power plants. Consequently, it will be necessary to create production-living complexes in orbit which include orbital stations (from which it would be possible to control the complex where people could live, rest, and so on) and also assembly yards and plants for the production of the station parts.

In spite of all of these problems, the problem of creating profitable orbital solar electric power plants does not in practice appear to be irresolvable. The statement of the problem itself already usually pushes the specialist to several versions of its possible solution. All of the problems are technically understandable and, as a rule, this means that they are theoretically solvable. If the operation of solar orbital electric power plants is possibly one of the basic areas of industrial activity of man in space in the next century, then, in the opinion of certain specialists, it will become possible much sooner to obtain electric power on orbital stations capable of influencing the earth's climate.

Actually, by directing energy fluxes using special radiators and the centers of formation of cyclones and typhoons, on individual points of meteorological fronts (when selecting the corresponding radiation bands), it is possible to disperse this energy on the earth's surface or at a given altitude of the earth's atmosphere, influencing the undesirable meteorological processes.

All of these examples indicate that industrial activity will in the future possibly become the basic sphere of activity of man in orbit around the earth both in the composition of the individual stations and on board scientific-applied production complexes having national economic significance.

The role of man in the operation of these complexes is entirely obvious, in spite of the proposed significant process in the automation of the set of individual operations during the operation of these complexes.

[288-10845]

10845
CSO: 1866

END